Plans and Draft Results:
Long-term Observations in Chesapeake Bay Open and Shallow Waters

CBP Modeling Workgroup
April 7, 2020
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With inputs from: Richard Tian and Qian Zhang (UMCES at CBP)

Motivation:

It appears that the CBP climate change scenarios predict more negative impacts on summer dissolved oxygen (DO) concentrations in Open and Shallow Water areas than in Deep Water, but it is still under investigation how well the estuarine model is capturing Open and Shallow response to rising air temperatures.

Rationale:

We can gain some insight into the estuarine model climate change predictions by analyzing the tidal long-term monitoring data and comparing patterns in temperature and DO over the last 30 years.

Topic 1: Open Water (OW)

CBP climate change scenarios predict that over approximately a 30-year period, summer DO concentrations in the Open Water (OW) designated use will be more negatively affected by climate change than summer DO in deeper layers. ***Do the magnitudes and depths of observed changes in the monitoring data support the modeling results that OW is more negatively affected than deeper water?***

Approach:

1. See how well monitored temperature change throughout the water column since the mid-1980s compares to estuarine model climate change predictions.

2. Investigate how well the past 30 years of DO saturation change throughout the water column compares to the estuarine model's climate change predictions.

Topic 2: Shallow Water (SW)

CBP climate change scenarios predict that DO in “shallow” waters (~1-3m total depth to bottom) will be more impacted than Open Water. ***Are the monitoring data showing evidence of this effect?***

Approach:

1. Evaluate whether the frequency of DO criteria violation has increased at a select set of shallow water monitoring stations over the period of record.

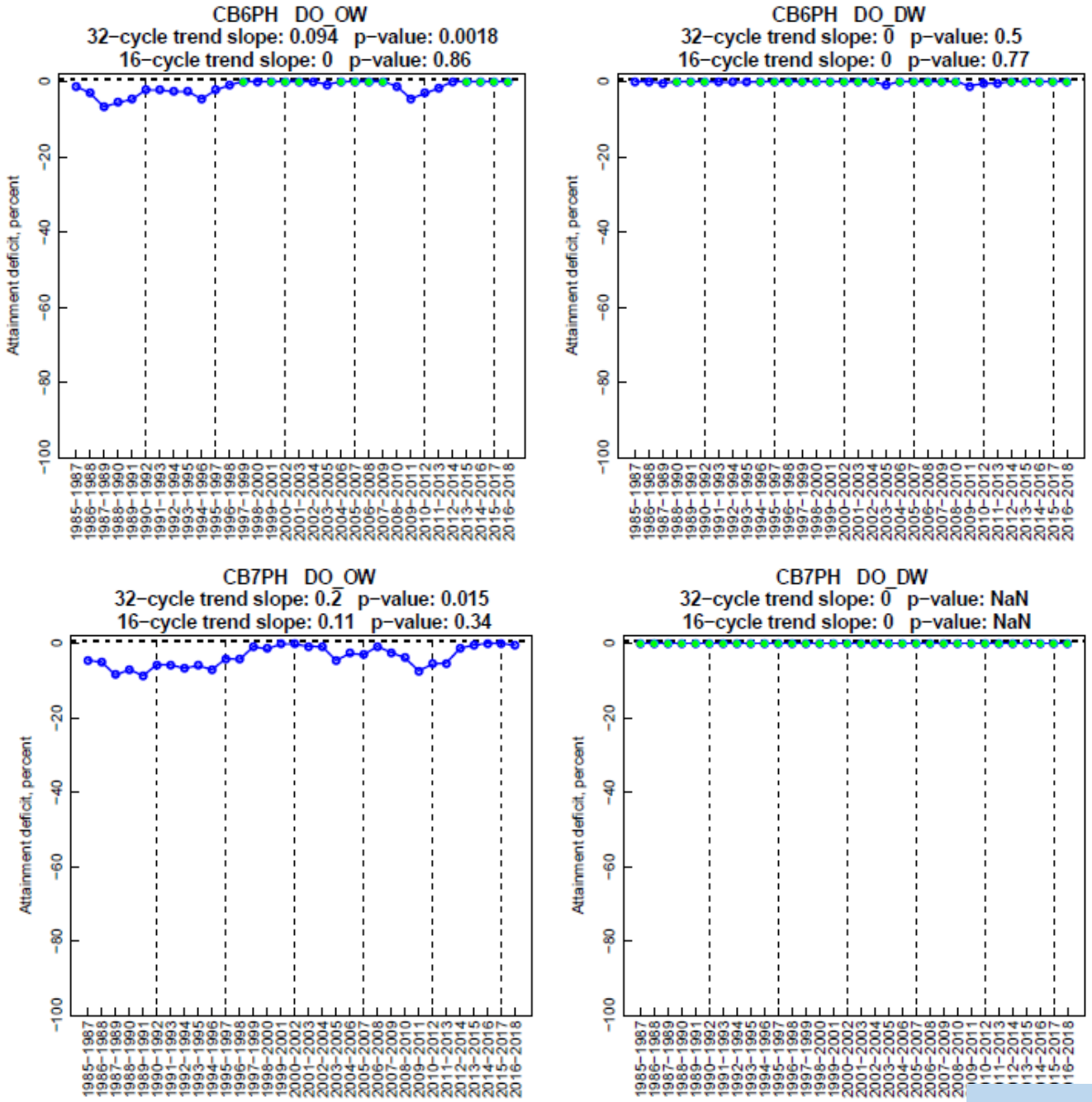
2. Investigate how water temperature change relates to DO criteria violation in shallow waters.

3. Compare temperature and DO trends in shallow water monitoring data to nearby long-term monitoring stations.

Attainment status

- Graphs indicate whether each segment has met the water quality criteria over time
  - Green dots are periods meeting the criterion
  - Blue dots are not meeting the criterion
- Y-axis "attainment deficit" shows how far away the segment is from attaining the criteria in space and time.

→ *over the long-term, OW attainment deficit is improving in both CB6PH and CB7PH*



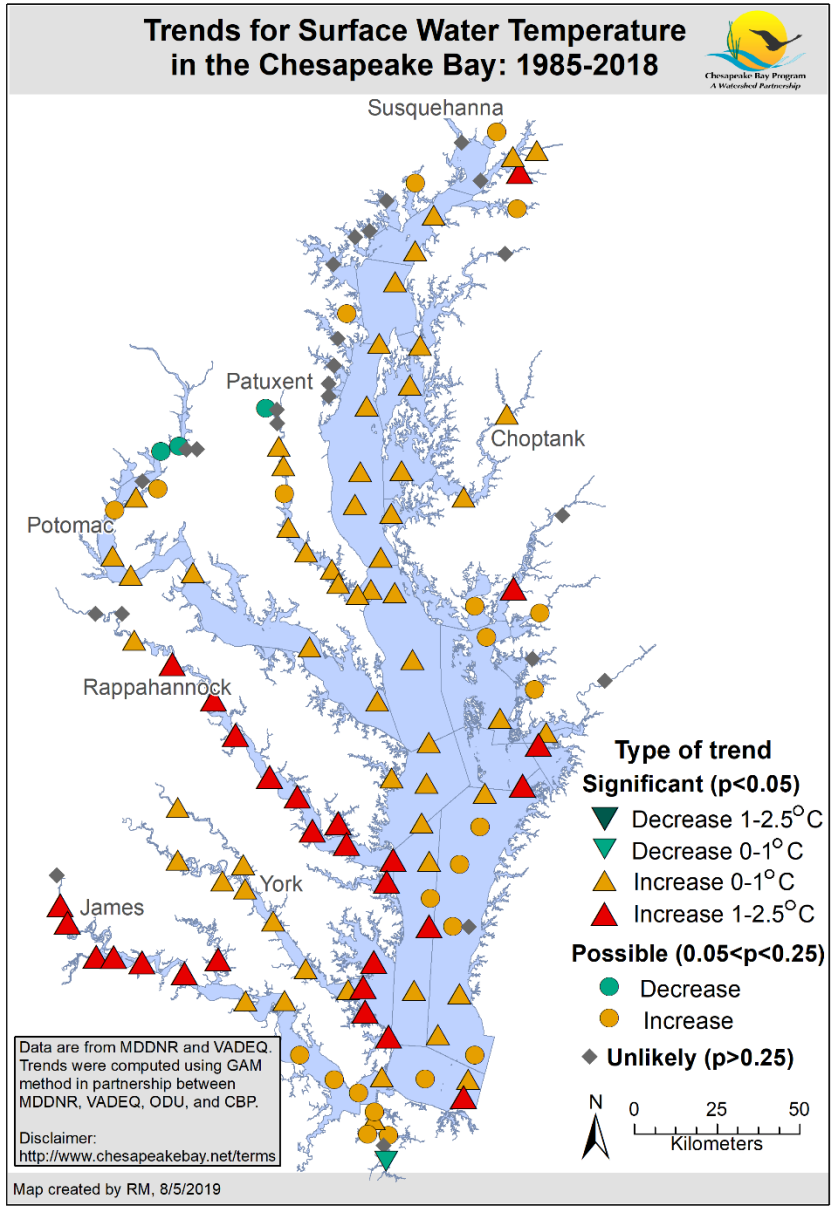
Based on Zhang et al. 2018 Front. Mar. Sci. 5:422. Updated by Qian Zhang for 2018.

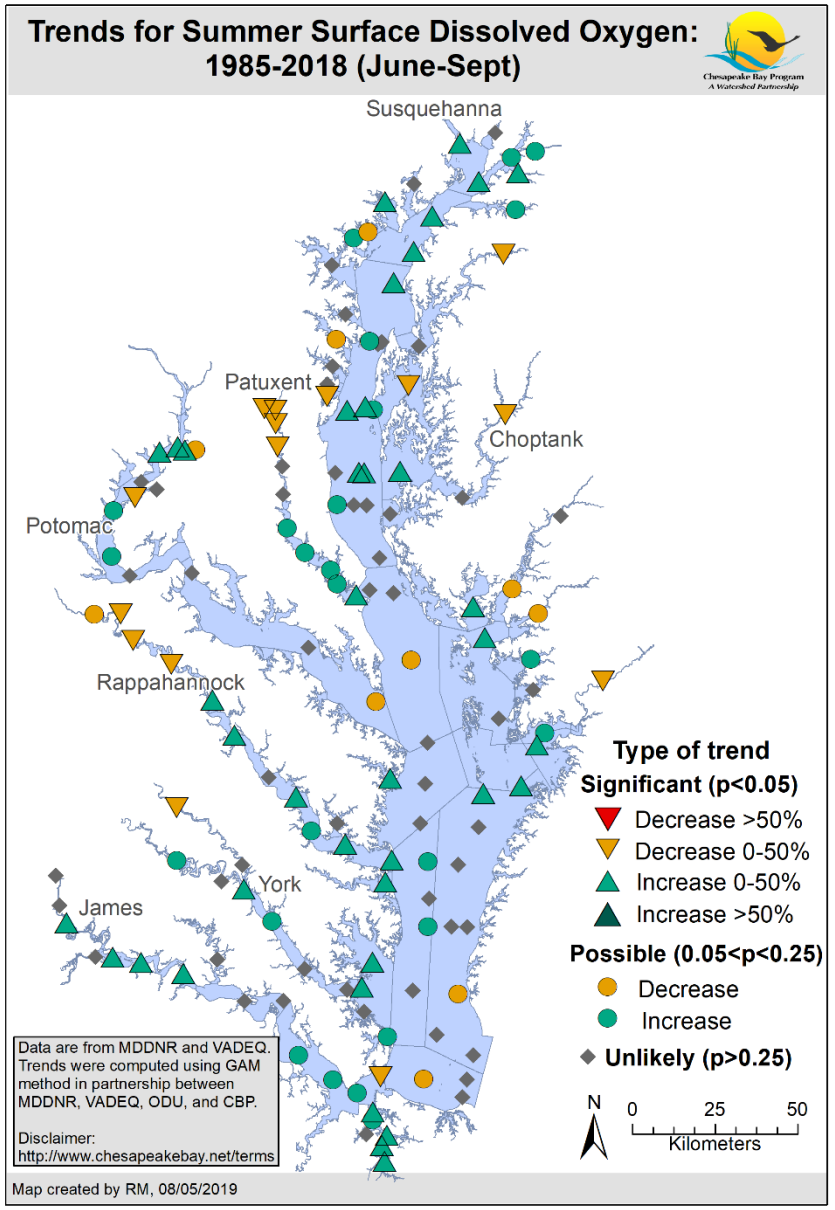
Topic 1: OW

Existing data analysis

- MD and VA state collaborators fit (generalized additive models) GAMs to DO and temperature annually, surface and bottom
- Surface temperature is increasing at almost all stations
- Surface DO trends are mixed

→ We can take this a step further and fit GAMs to the data at each depth at each station to see if there are patterns with depth



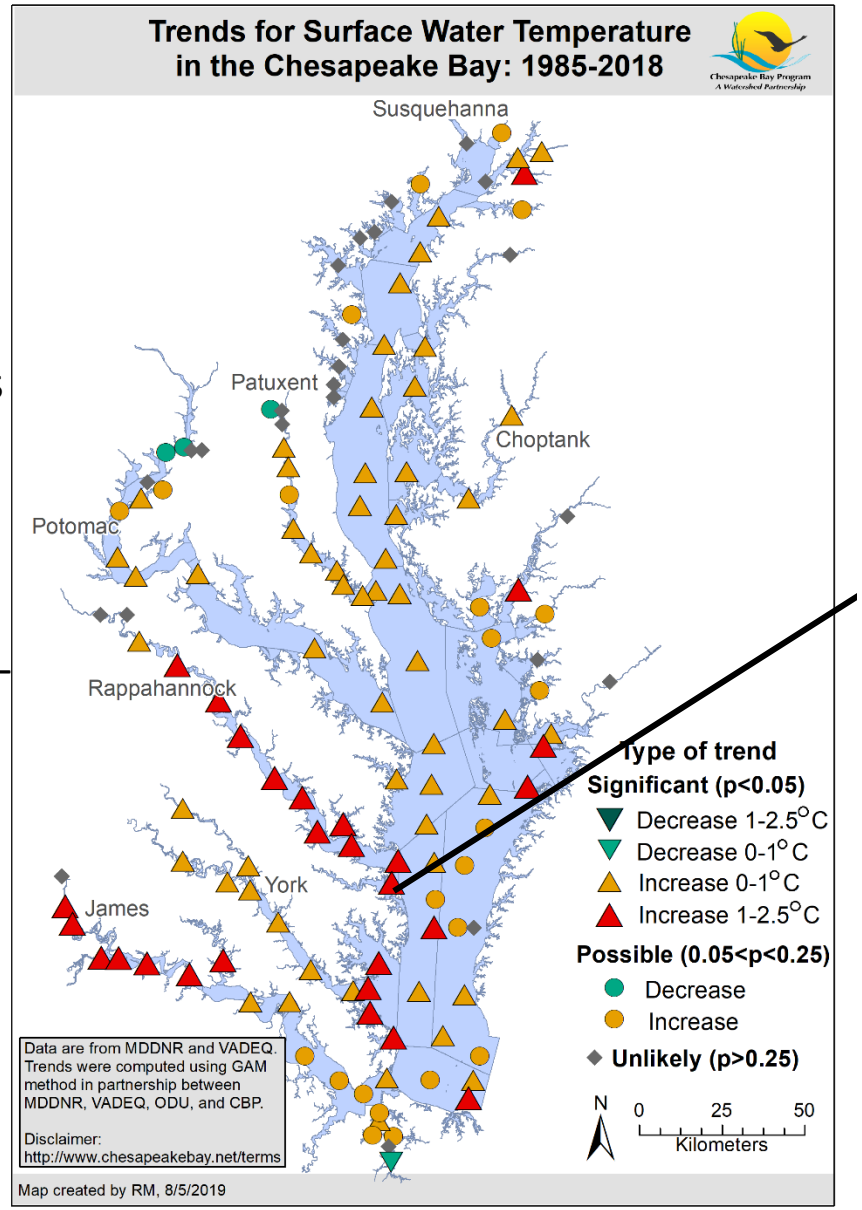


https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team

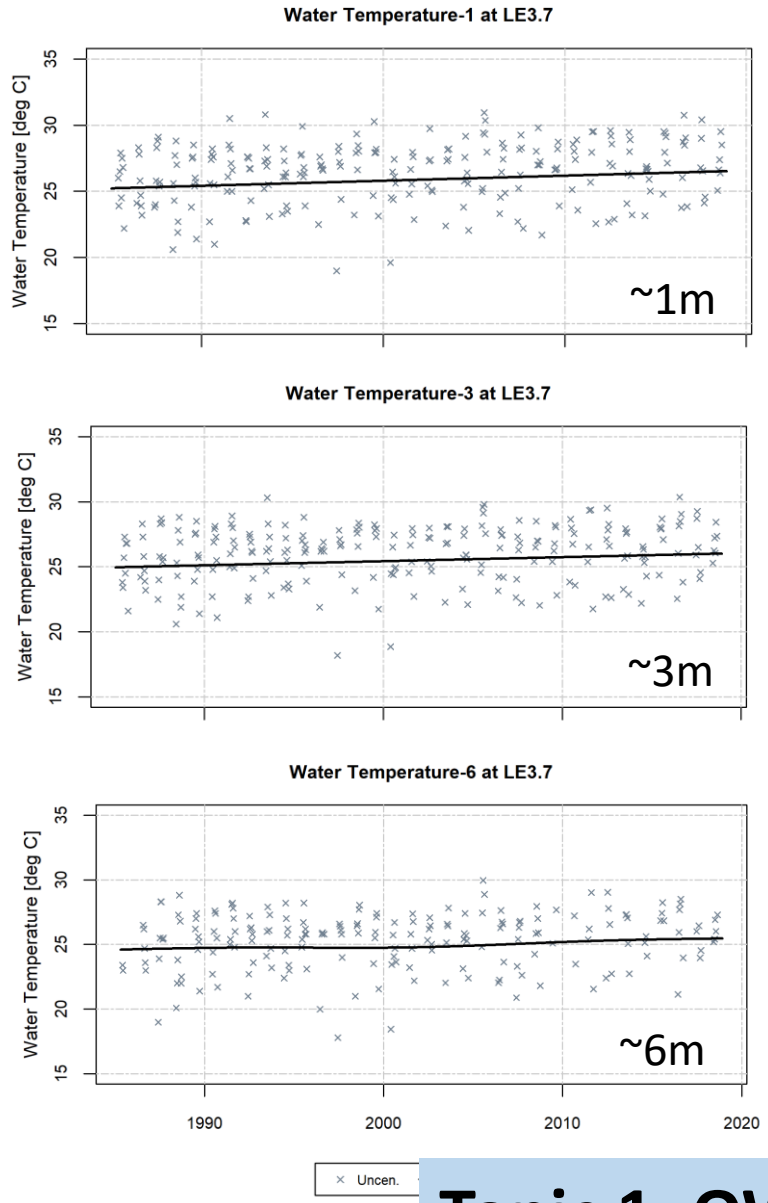
Topic 1: OW

Extended data analysis

1. Compile and identify any depth at any station with >300 samples from the 1980s to 2018 (DO, temp, salinity, computed DO-saturation)
2. Fit a GAM to evaluate change over time at each unique station-depth-parameter data set



Summer (June-Sept) only excerpts from full annual fit



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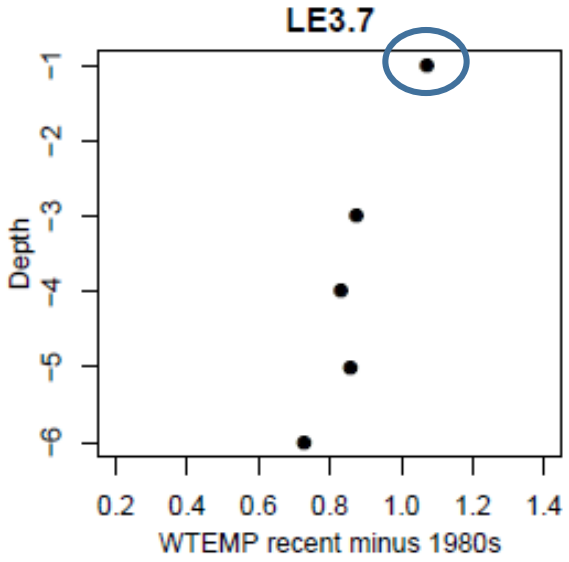
Extended data analysis

1. Compile and identify any depth at any station with >300 samples from the 1980s to 2018 (DO, temp, salinity, computed DO-saturation)
2. Fit a GAM to evaluate change over time at each unique station-depth-parameter data set
3. Identify years from the beginning to end to compute change. Tested options, and settled on two 5-year periods with similar average input river flow (1985-1989 to 2013-2017)
4. Compute change, make plots by depth

Summer (June-Sept) change: 2013 to 2017 temperature minus 1985 to 1989 temperature



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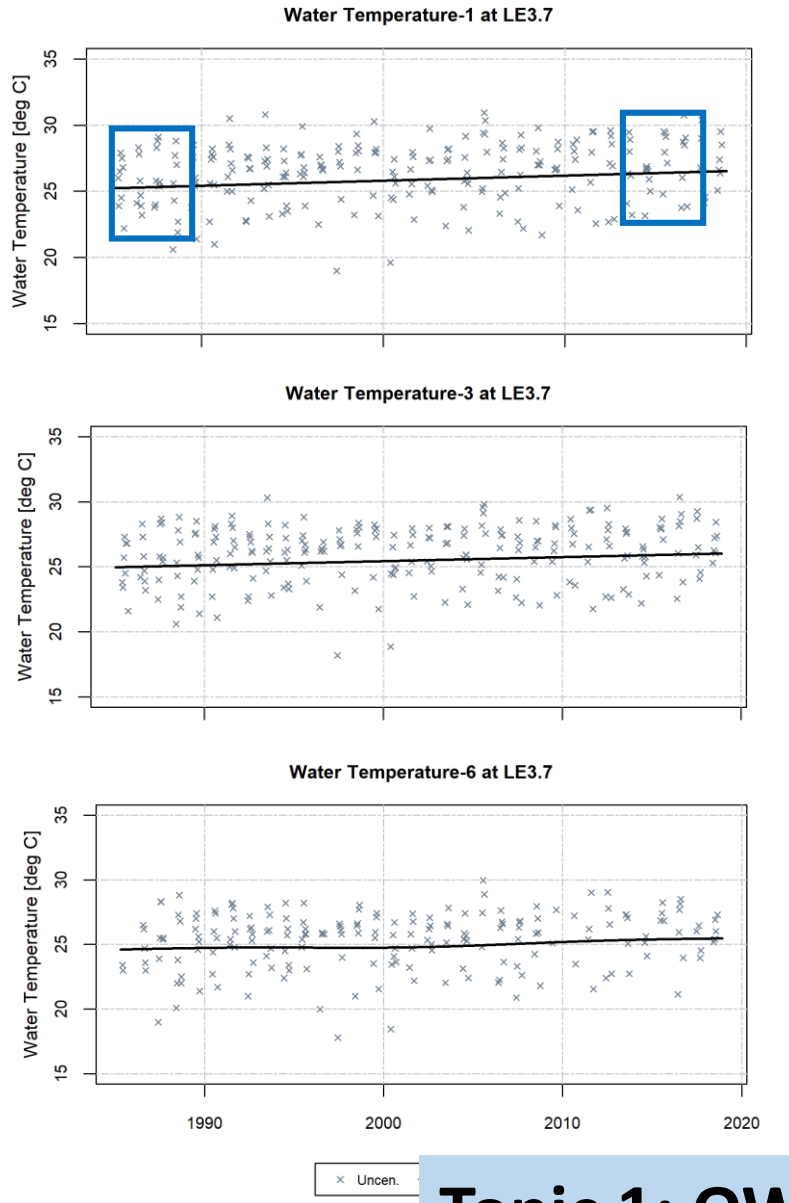

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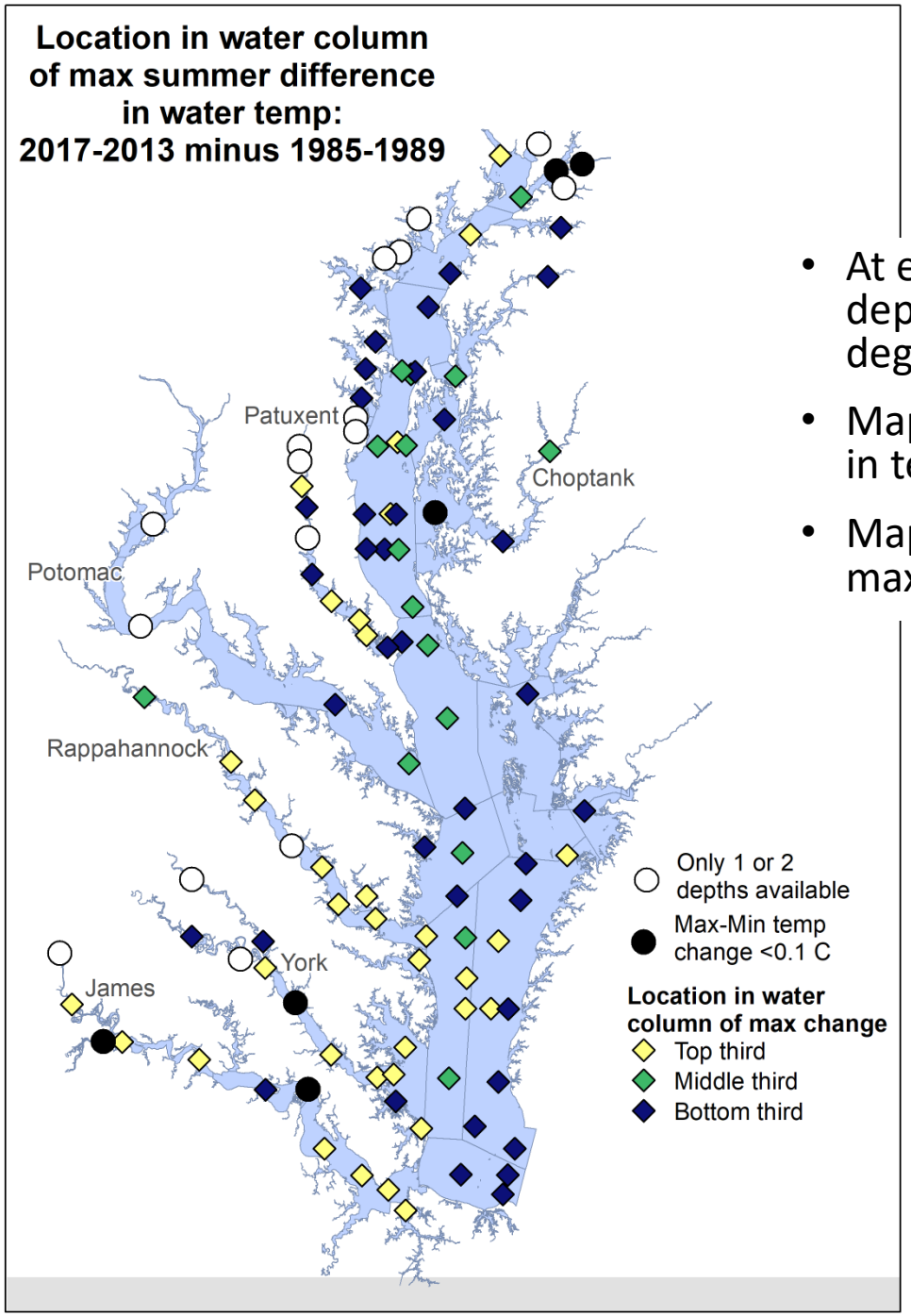
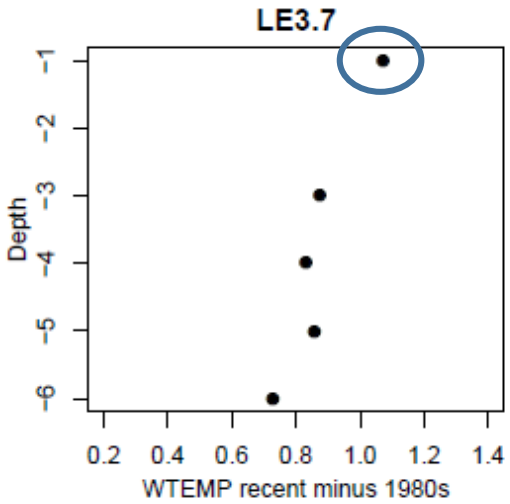
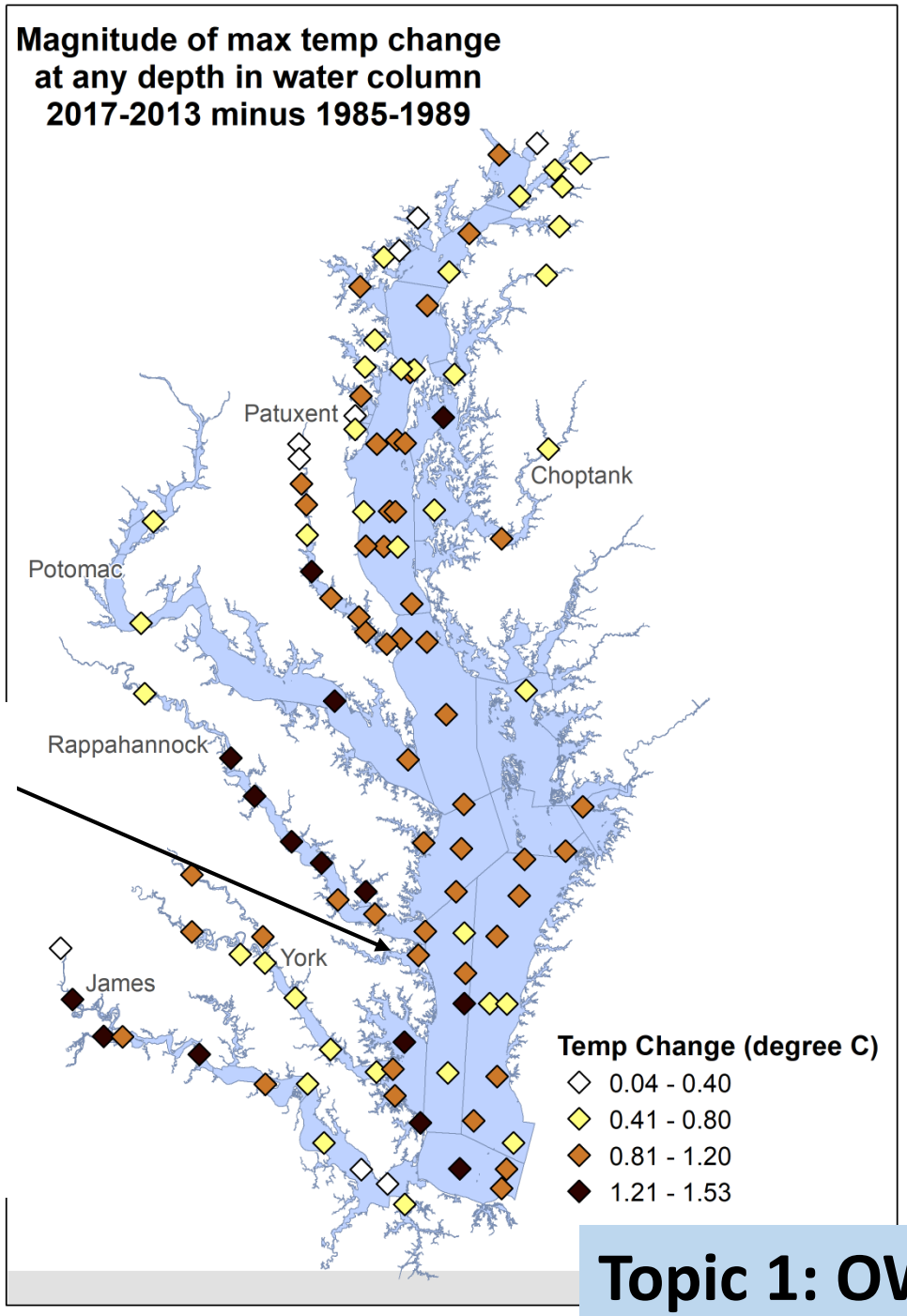


- At each station, identify the depth with the largest degree change over time
- Map the maximum changes in temperature
- Map the depth of the maximum change





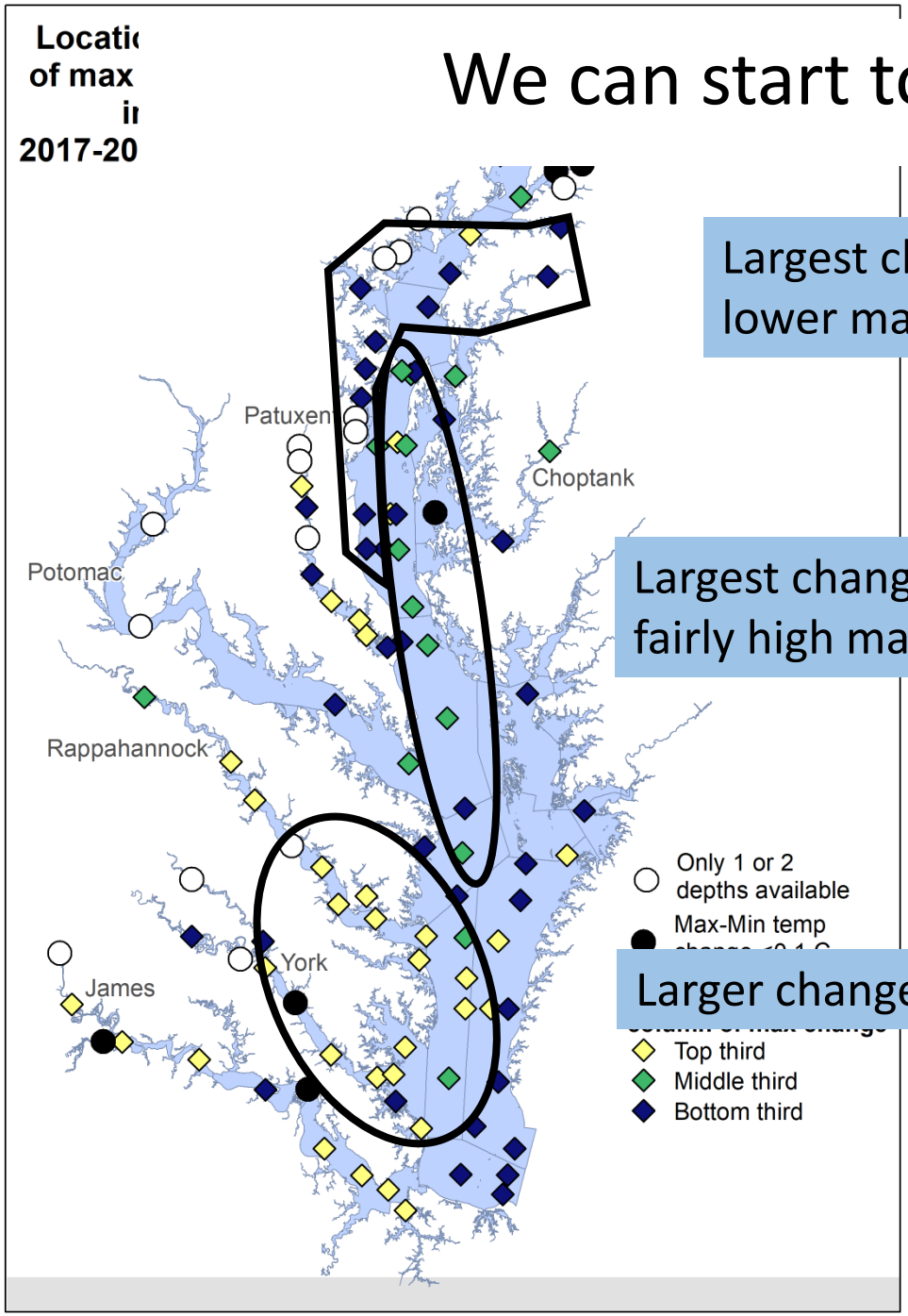
Topic 1: OW

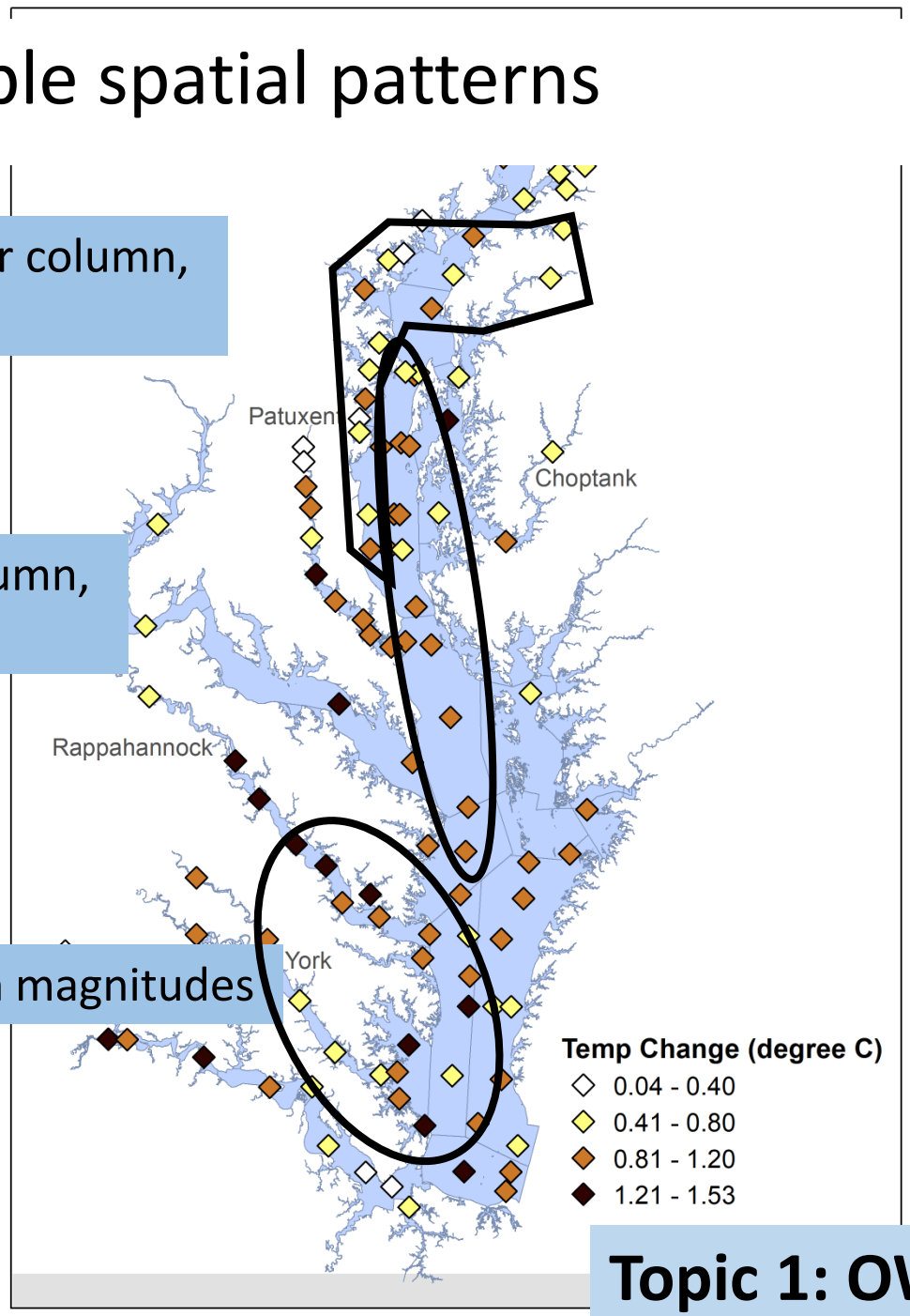
We can start to dig into possible spatial patterns

Largest change in bottom of water column, lower magnitudes

Largest change in middle of water column, fairly high magnitudes

Larger change near surface, fairly high magnitudes





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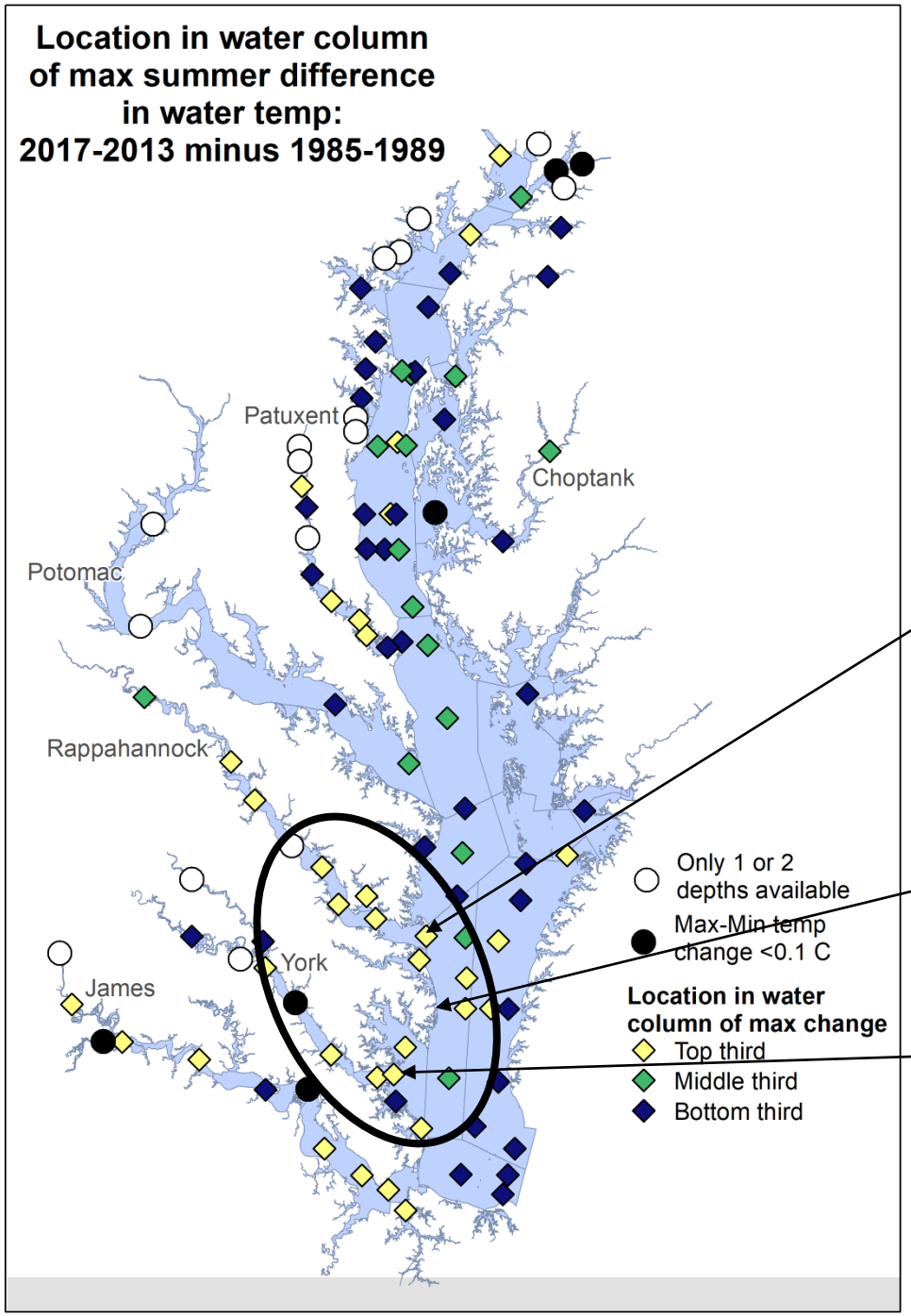
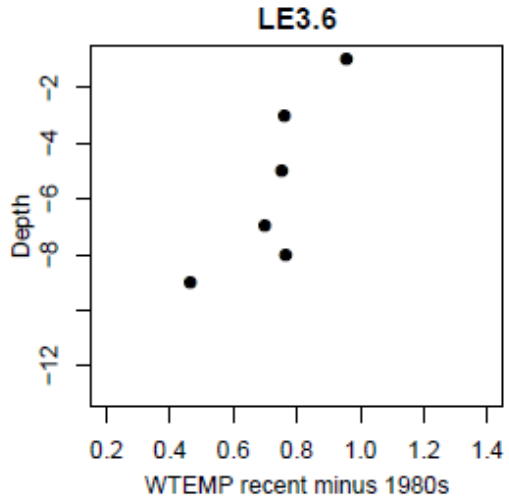
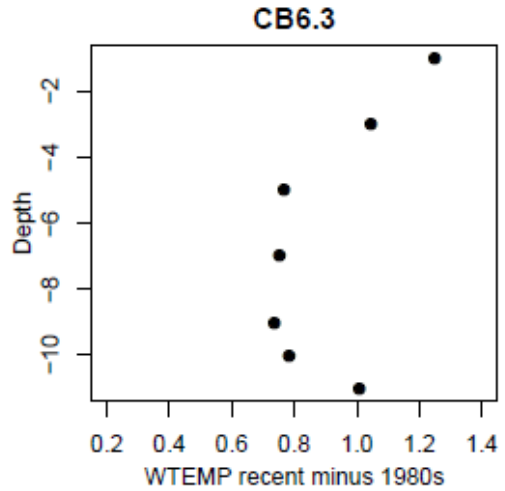
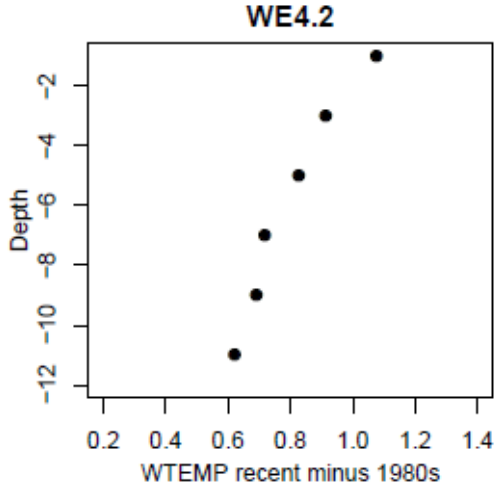


Lower Bay, western shore:
Larger change near surface, fairly high magnitude of change







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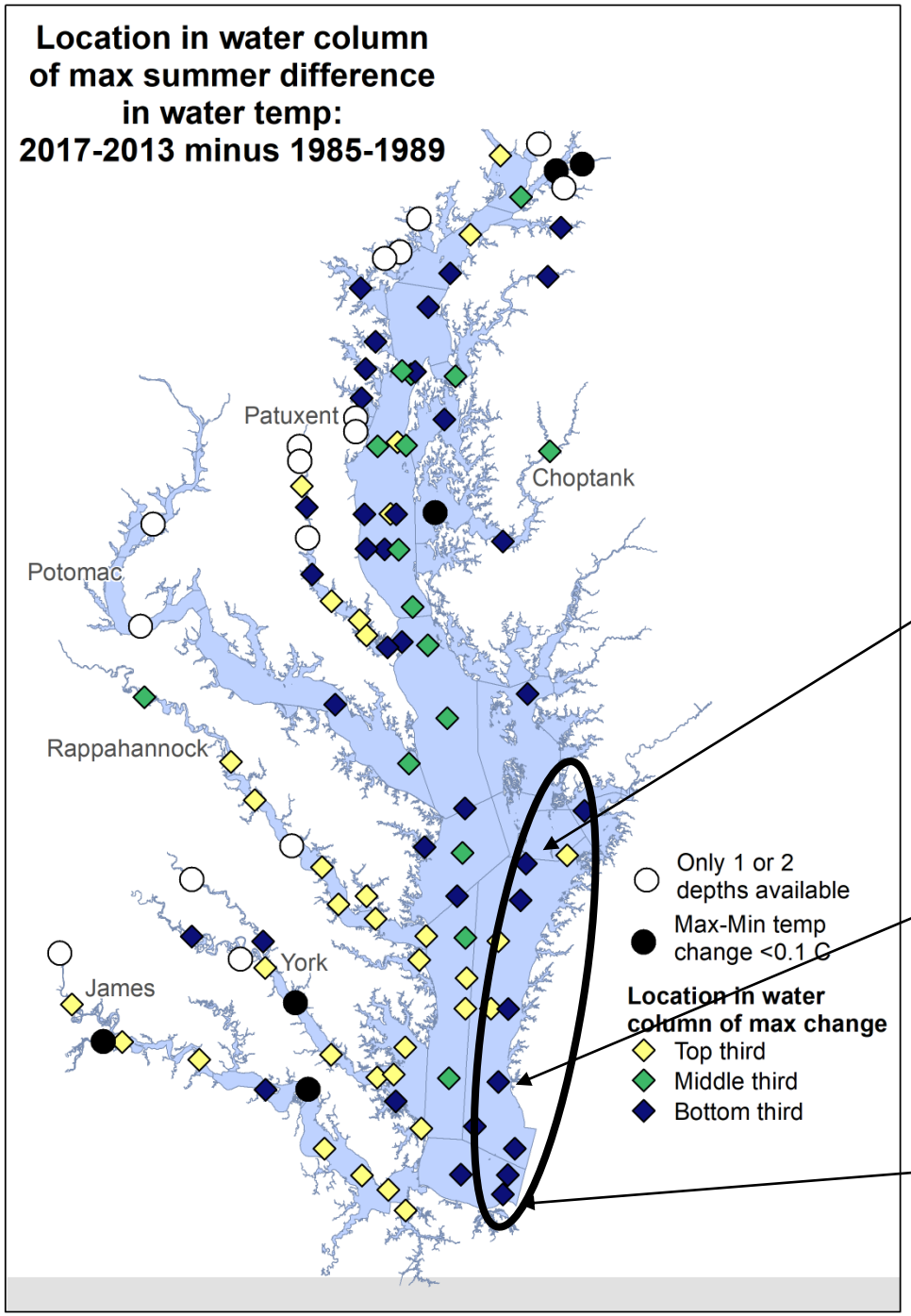
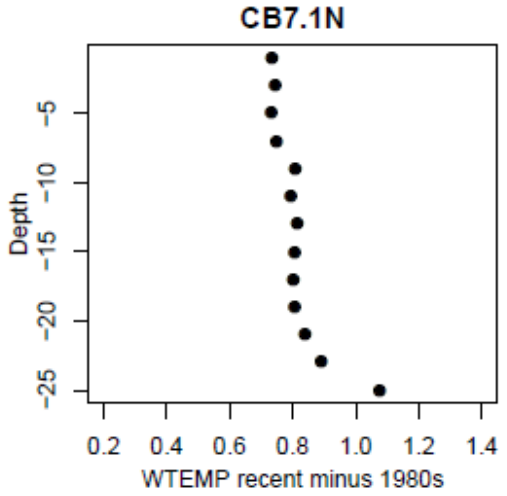
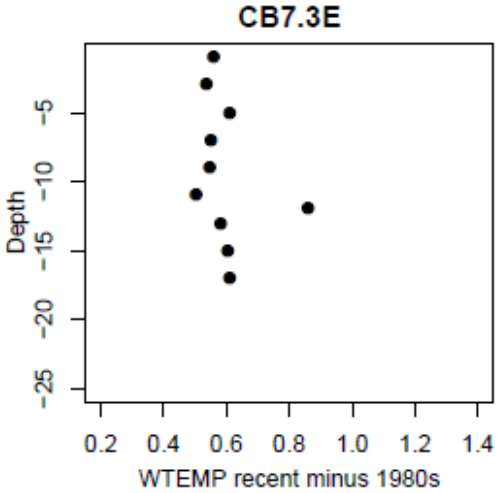
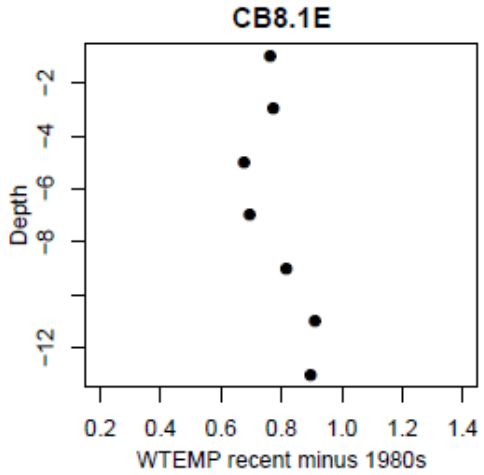




But surface increase the highest is not universally the pattern in lower bay. I think CB7PH is mixed, and CB8PH is definitely not.





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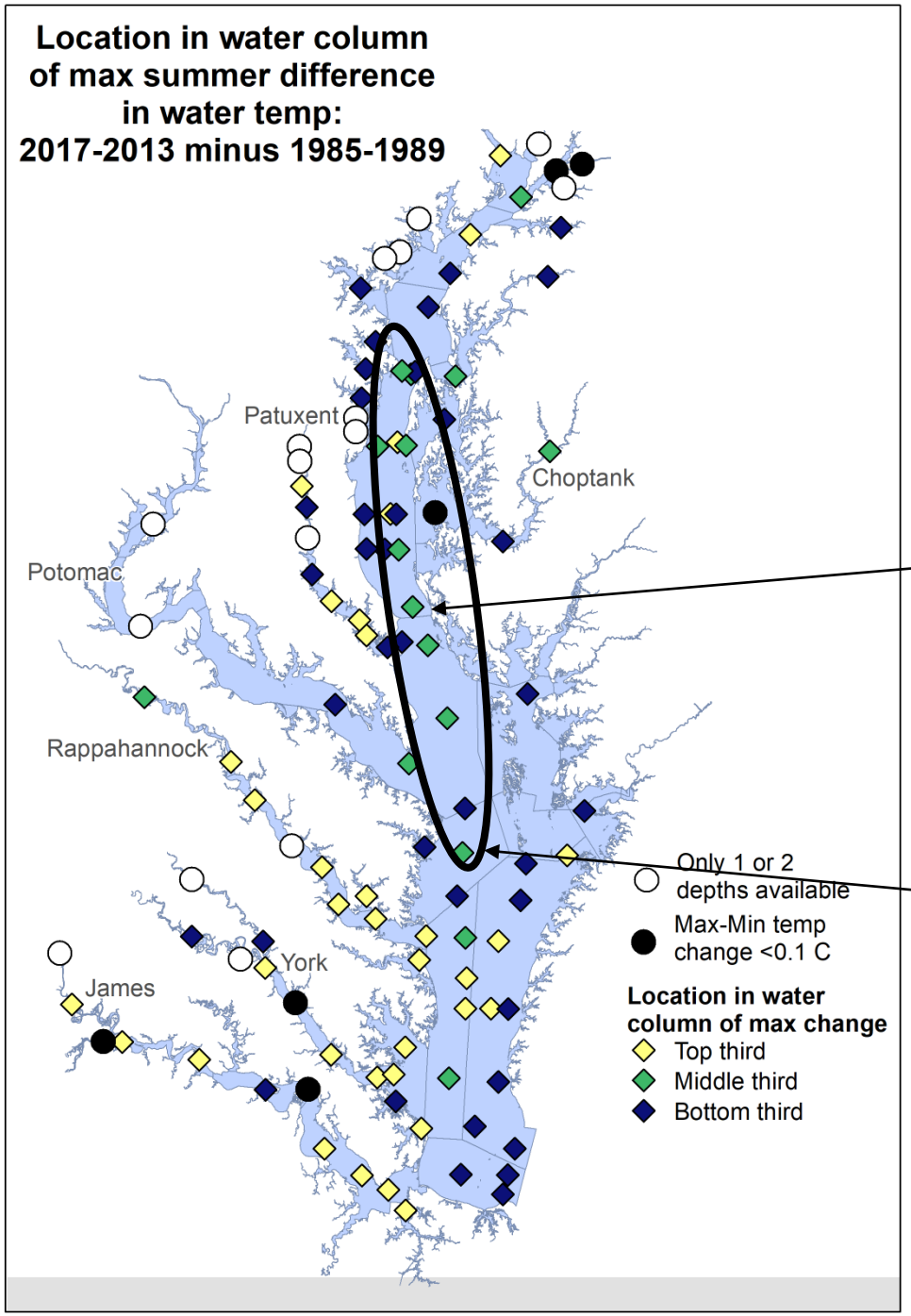
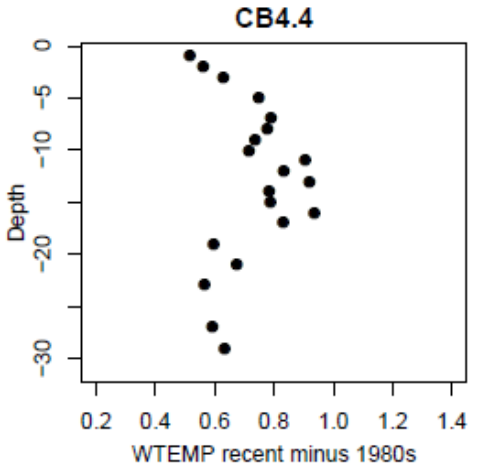
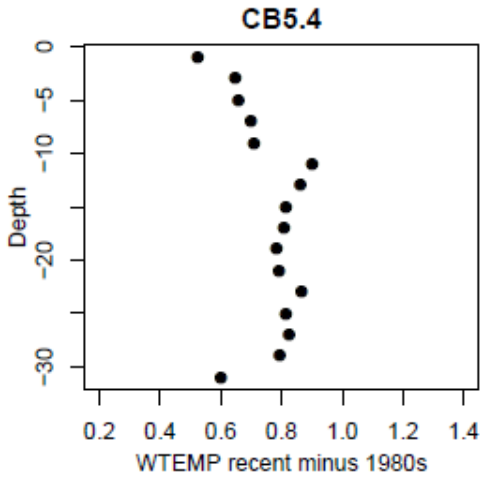


Mid-bay stations: Largest change in middle of water column, or relatively constant with depth





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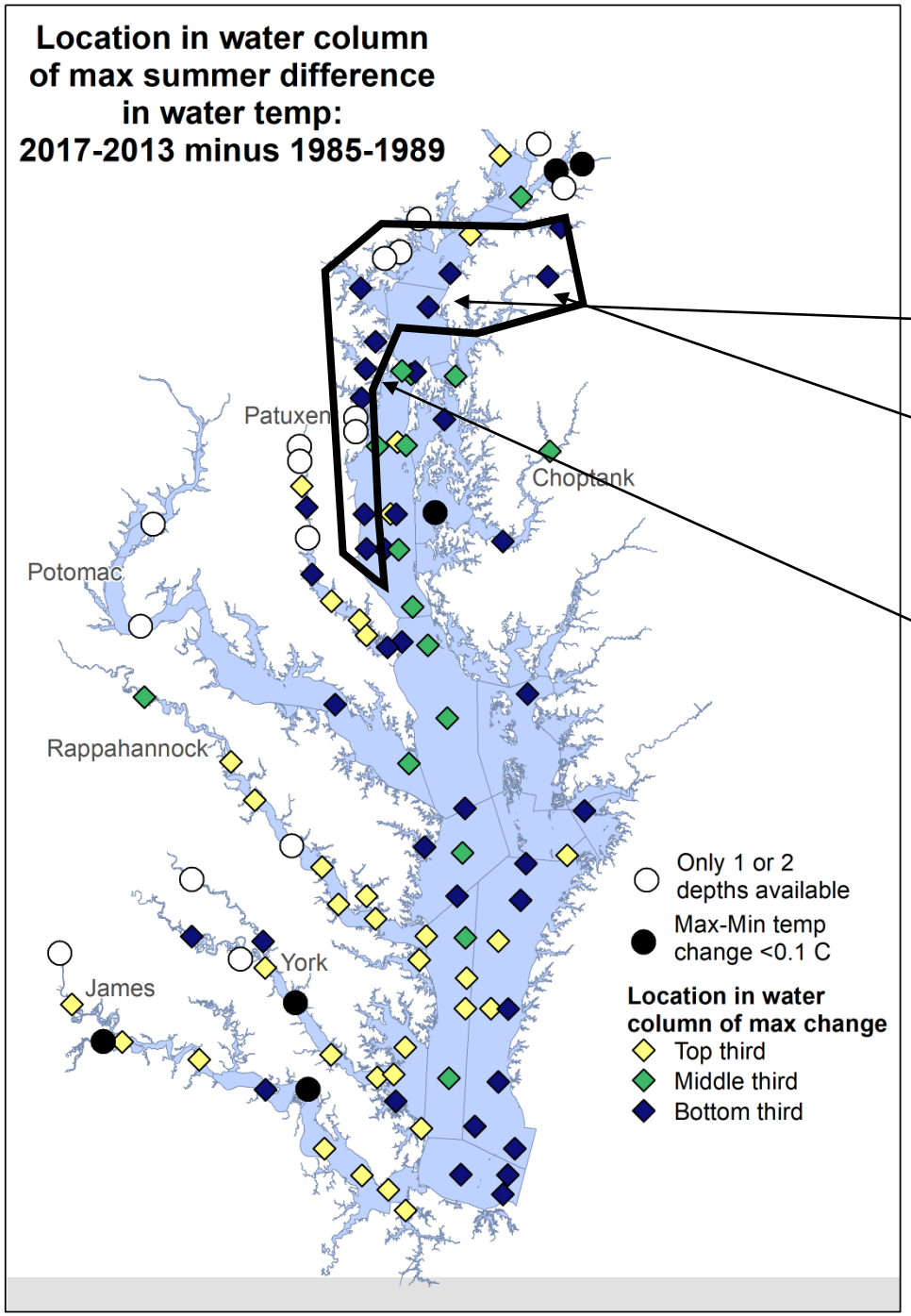
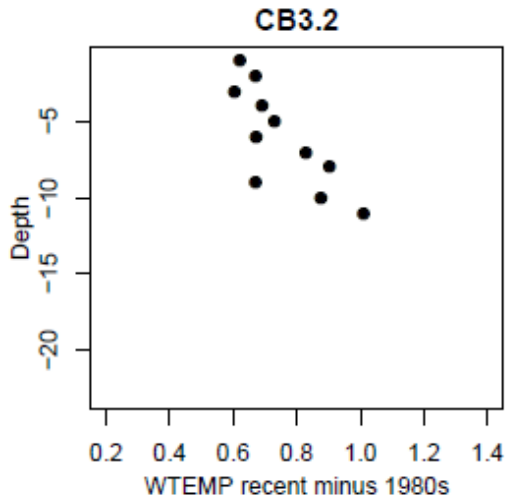
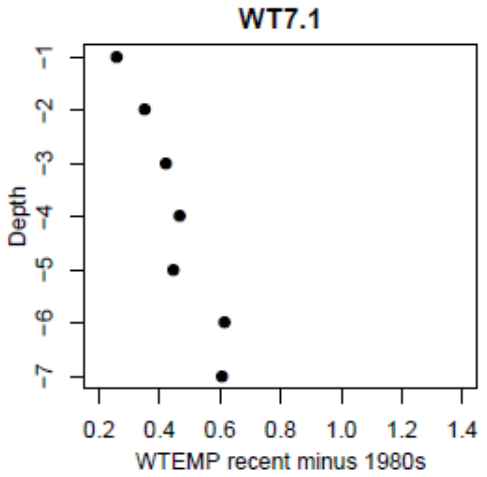
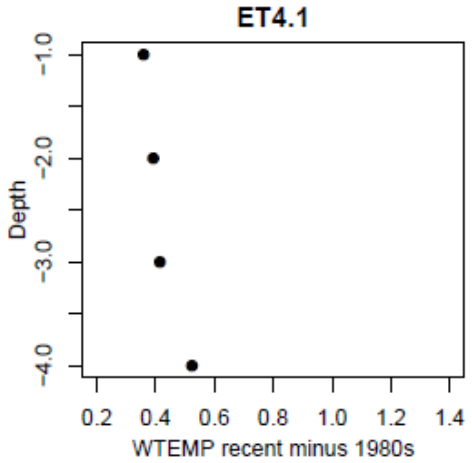


Many upper bay tributary and the OH stations: Largest change in bottom of water column, lower magnitude of change



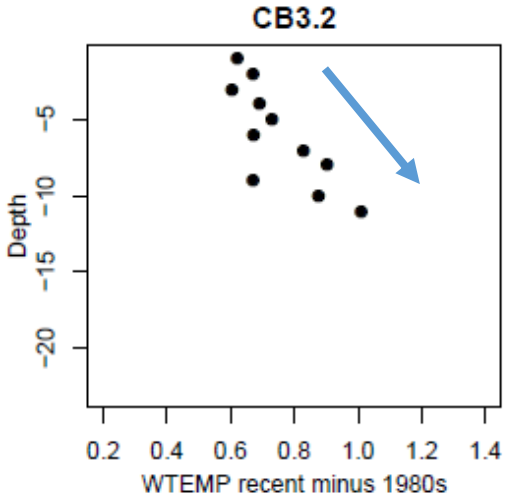


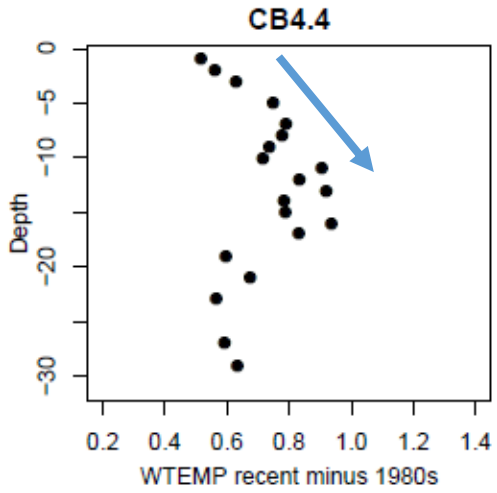


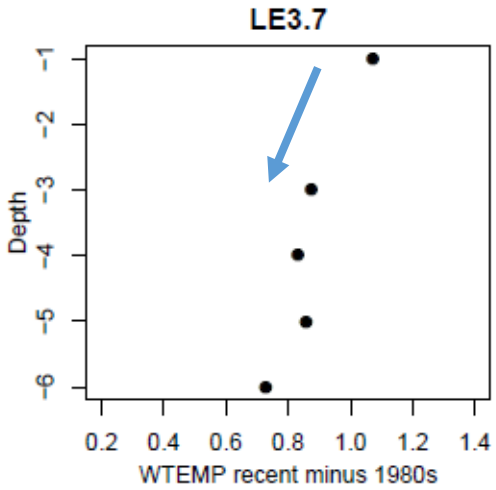
Topic 1: OW

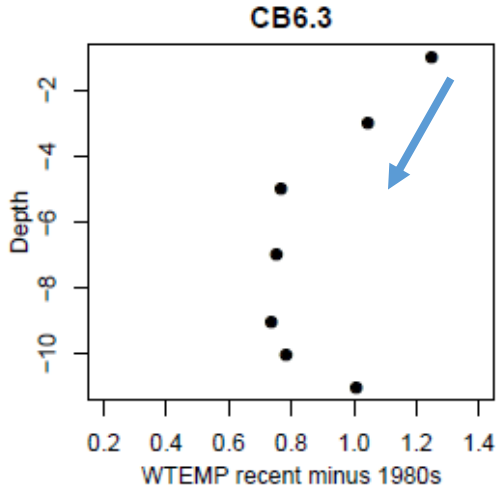
Open Water Temperature: How do these compare to model results?

Monitoring: Summer difference between 2013 to 2017 minus 1985 to 1989

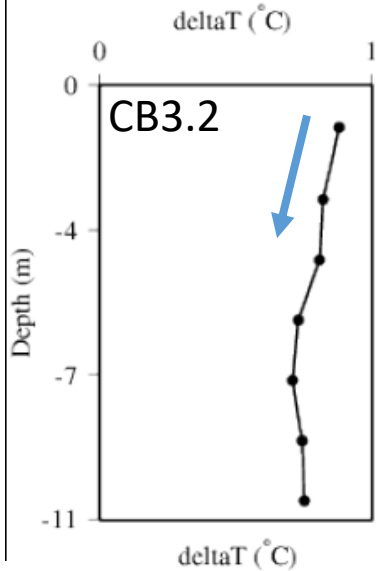


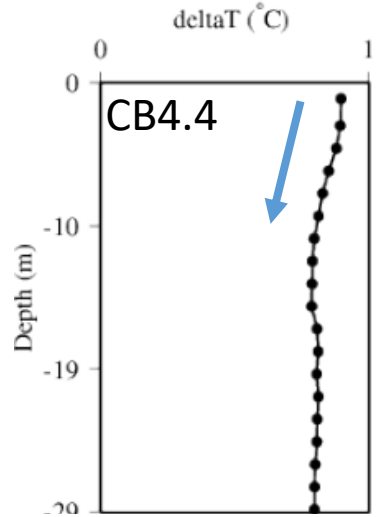




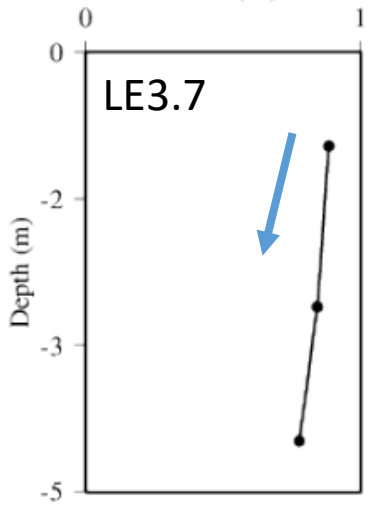


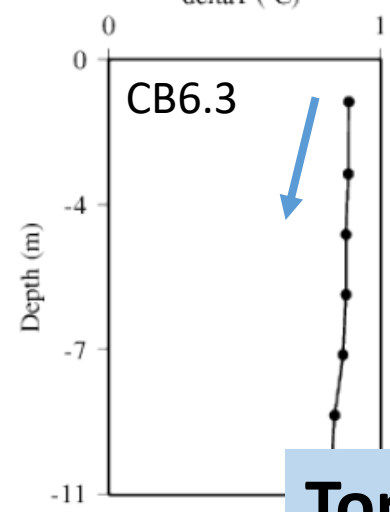
Model: Summer difference between climate change scenario centered on 2025 and 1991-2000 simulation





Modeling and monitoring are different for stations where largest change in the data is NOT at the surface.





More similar with depth when largest temp change in the data is at the surface.

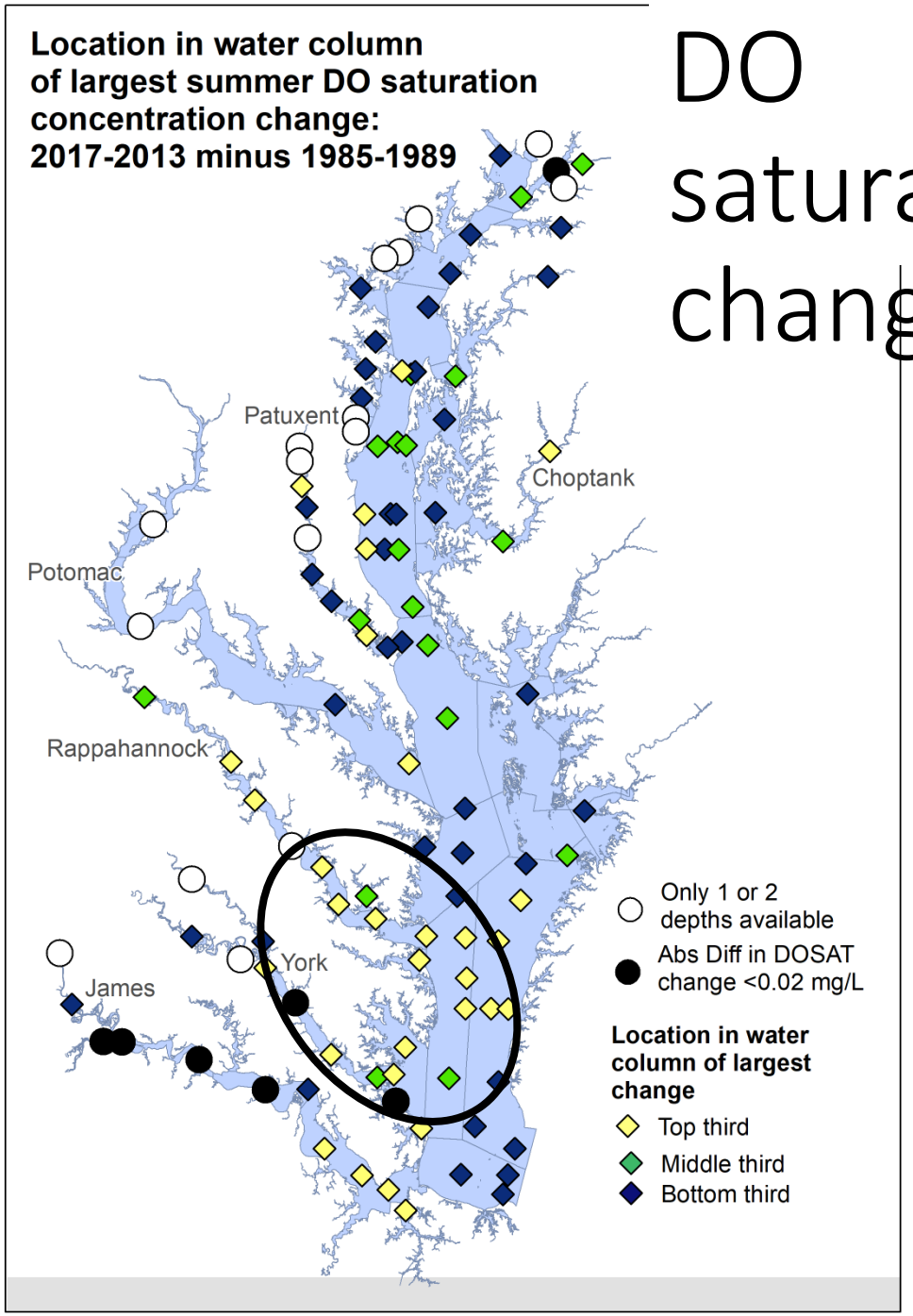
From Richard Tian

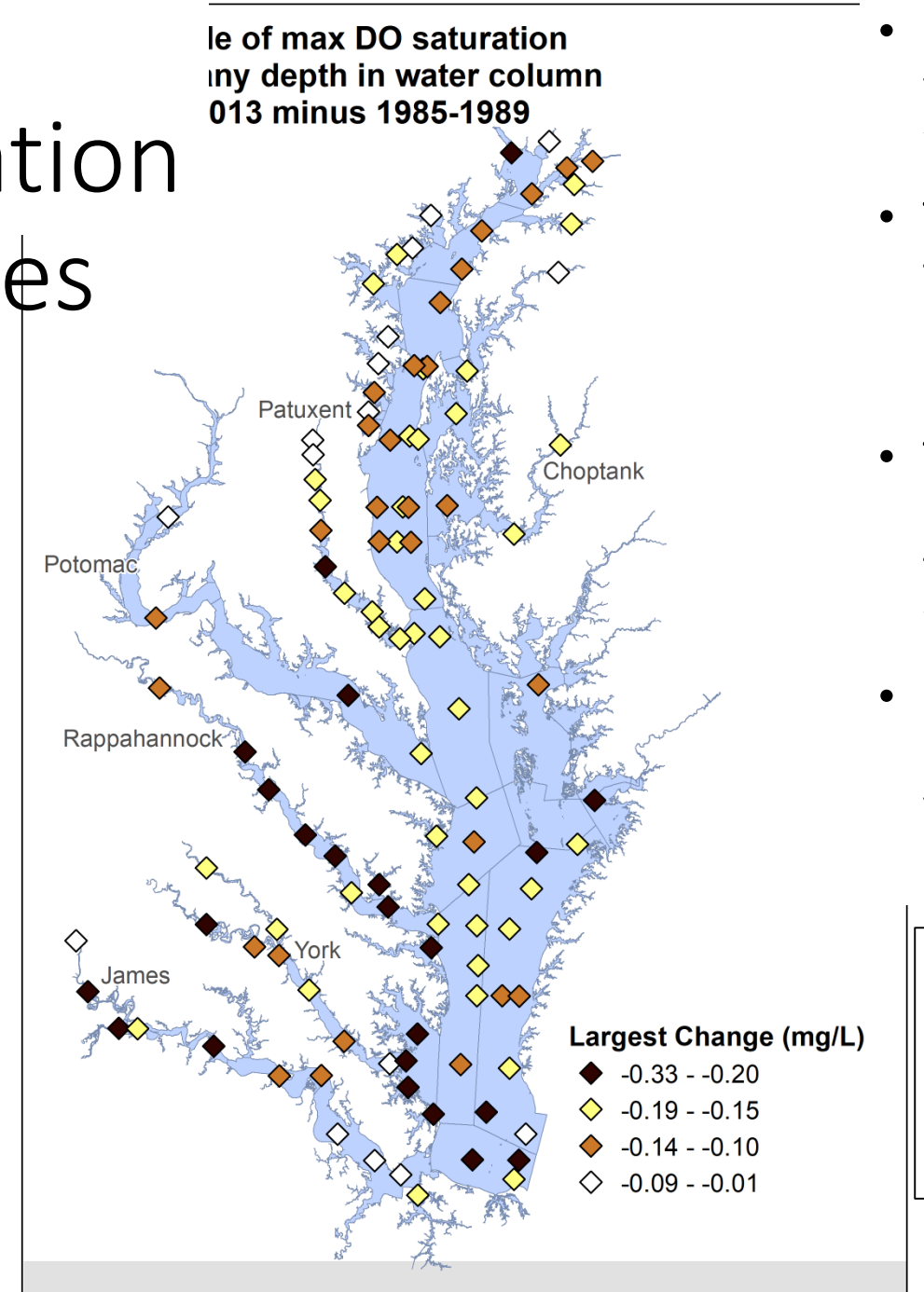
Topic 1: OW

Open water: DO saturation changes

- Computed and analyzed DO-saturation with the same approach as temperature to start to address questions:
  - Could decreases in DO saturation due to temperature increases be impacting the ability to meet Open Water Criteria?

DO saturation changes



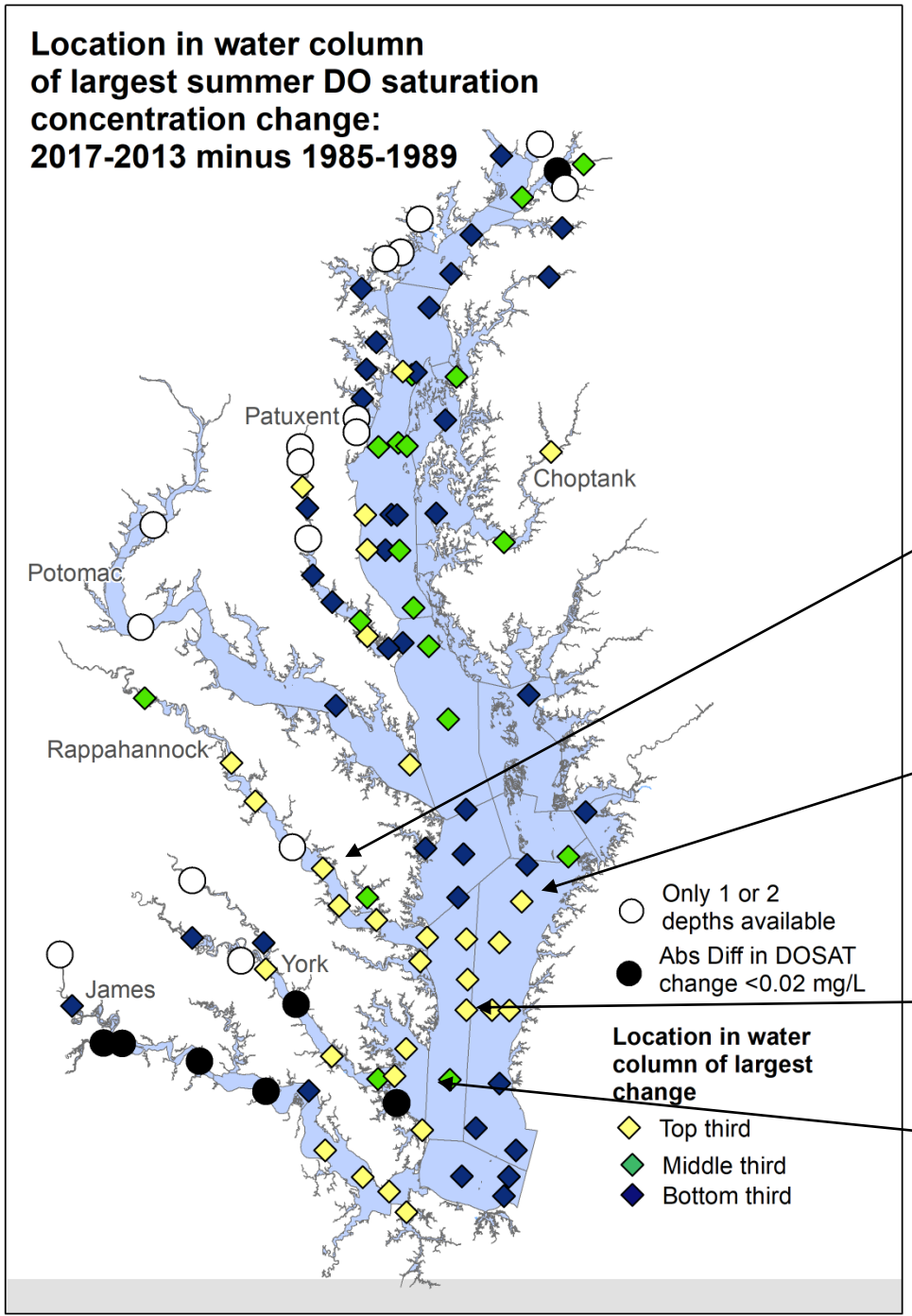


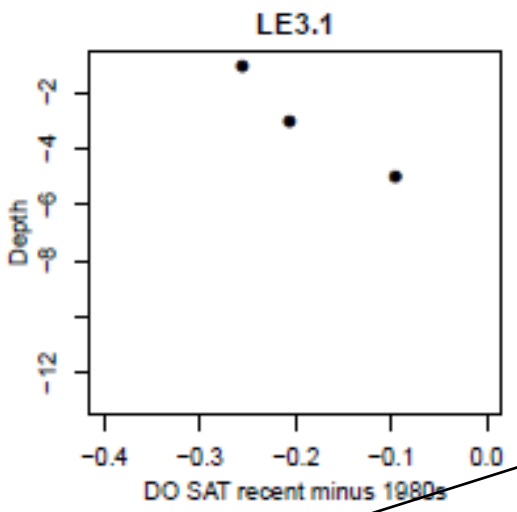
- Spatial patterns are very consistent with water temp.
- The magnitude of the DO saturation changes varies from 0 to -0.33 mg/L.
- The largest changes mostly appear in the lower tidal waters.
- Bay-wide, the depth of max change varies.

Note: these are the total change over ~28 years. Divide by 28 to get change per year. Or 3 to get change/decade.

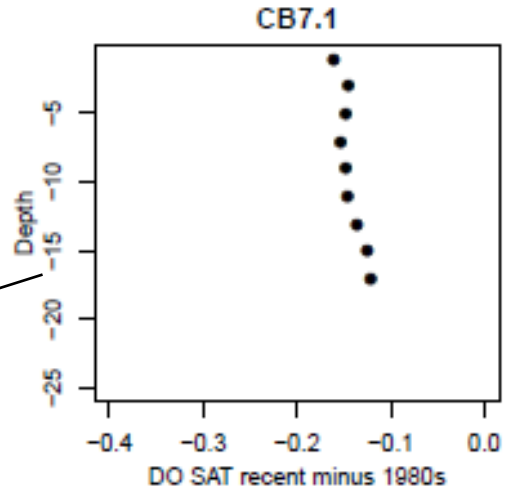
Topic 1: OW

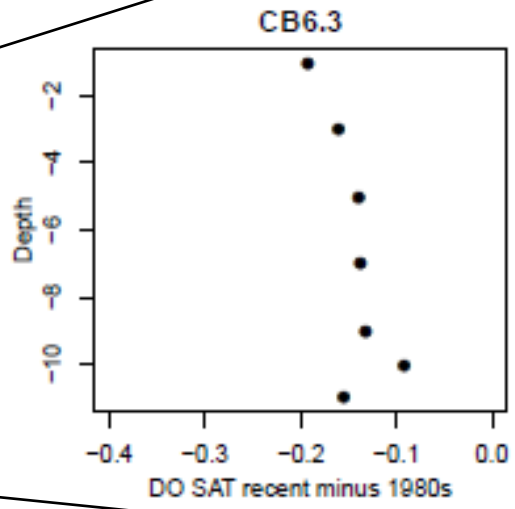
Locations where DO Saturation is decreasing the most near the surface

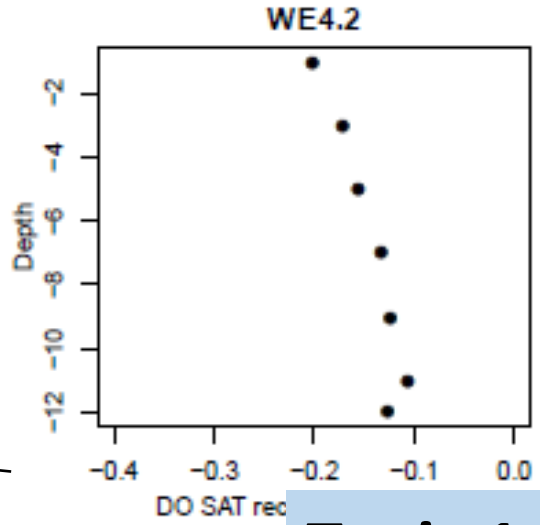




Same locations where temperature is increasing the most at the surface







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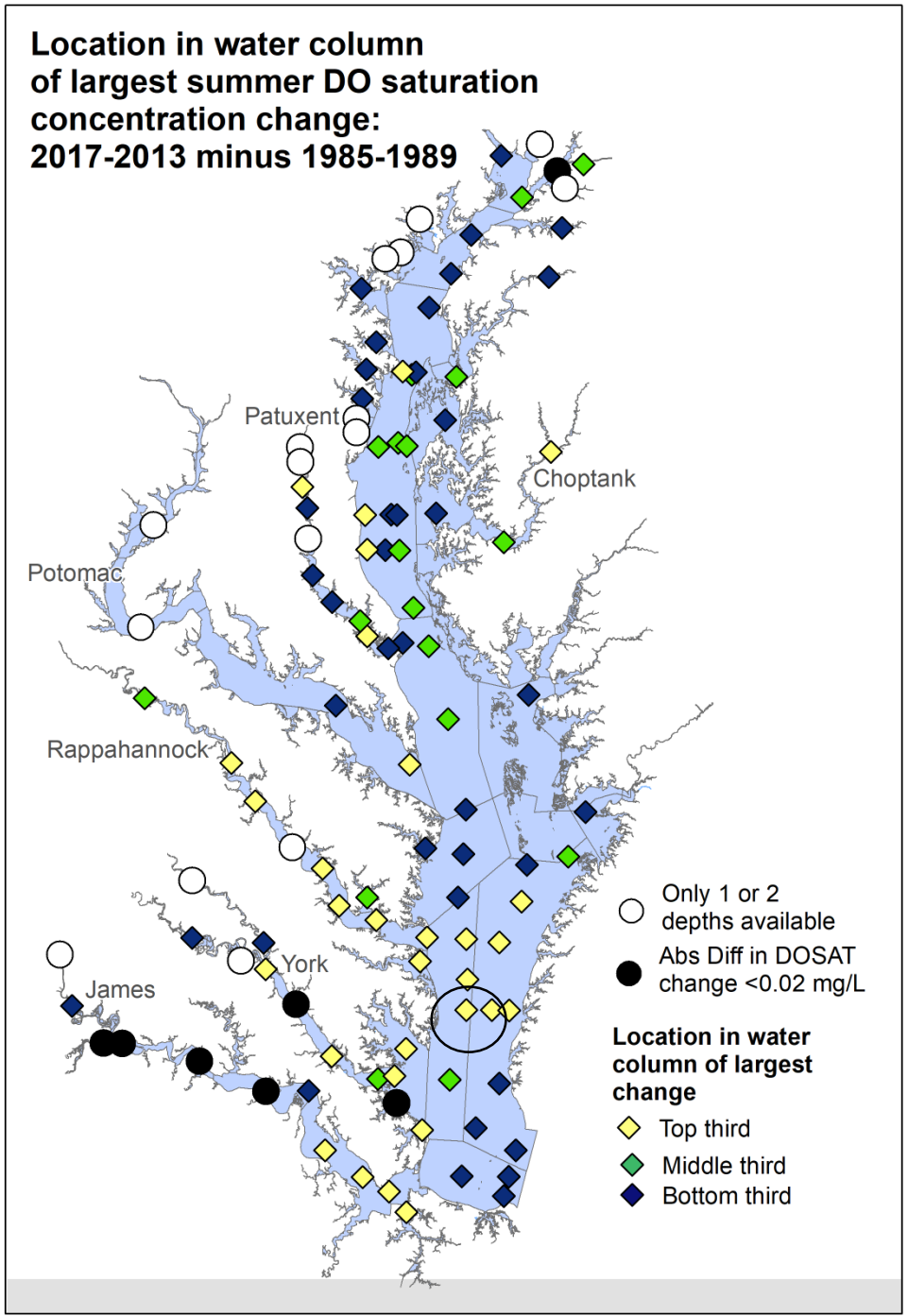
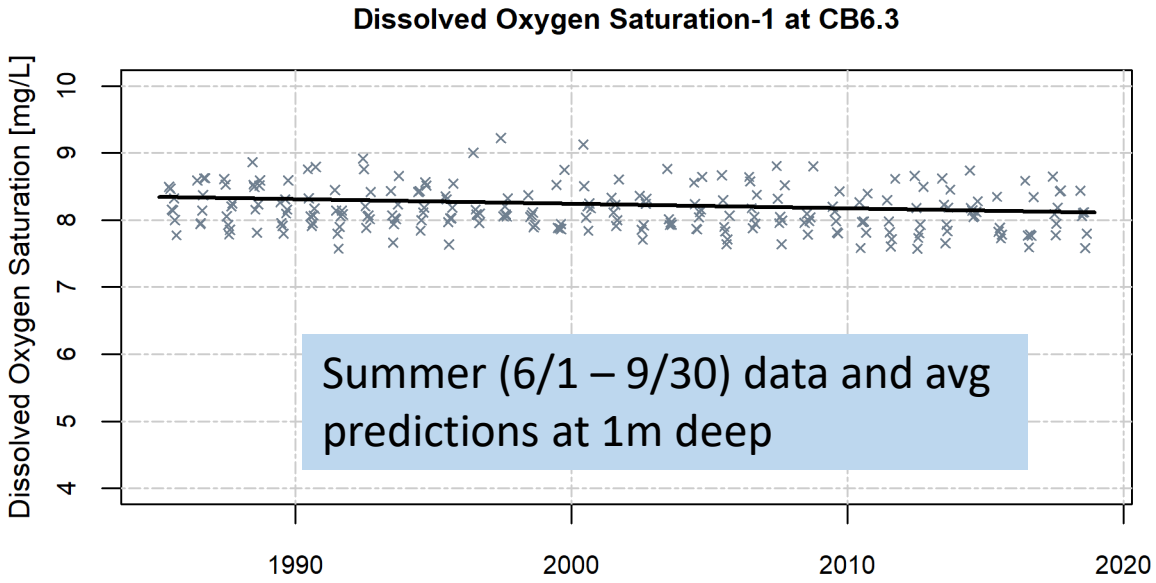
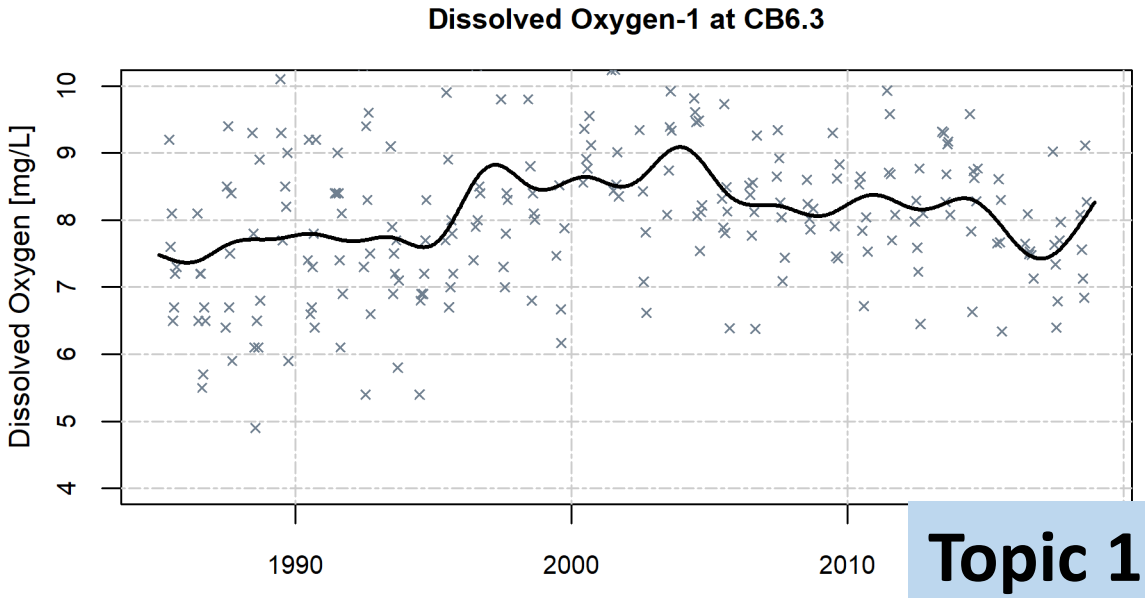


DO Saturation: Example graphs showing change over time



Summer (6/1 – 9/30) data and avg predictions at 1m deep



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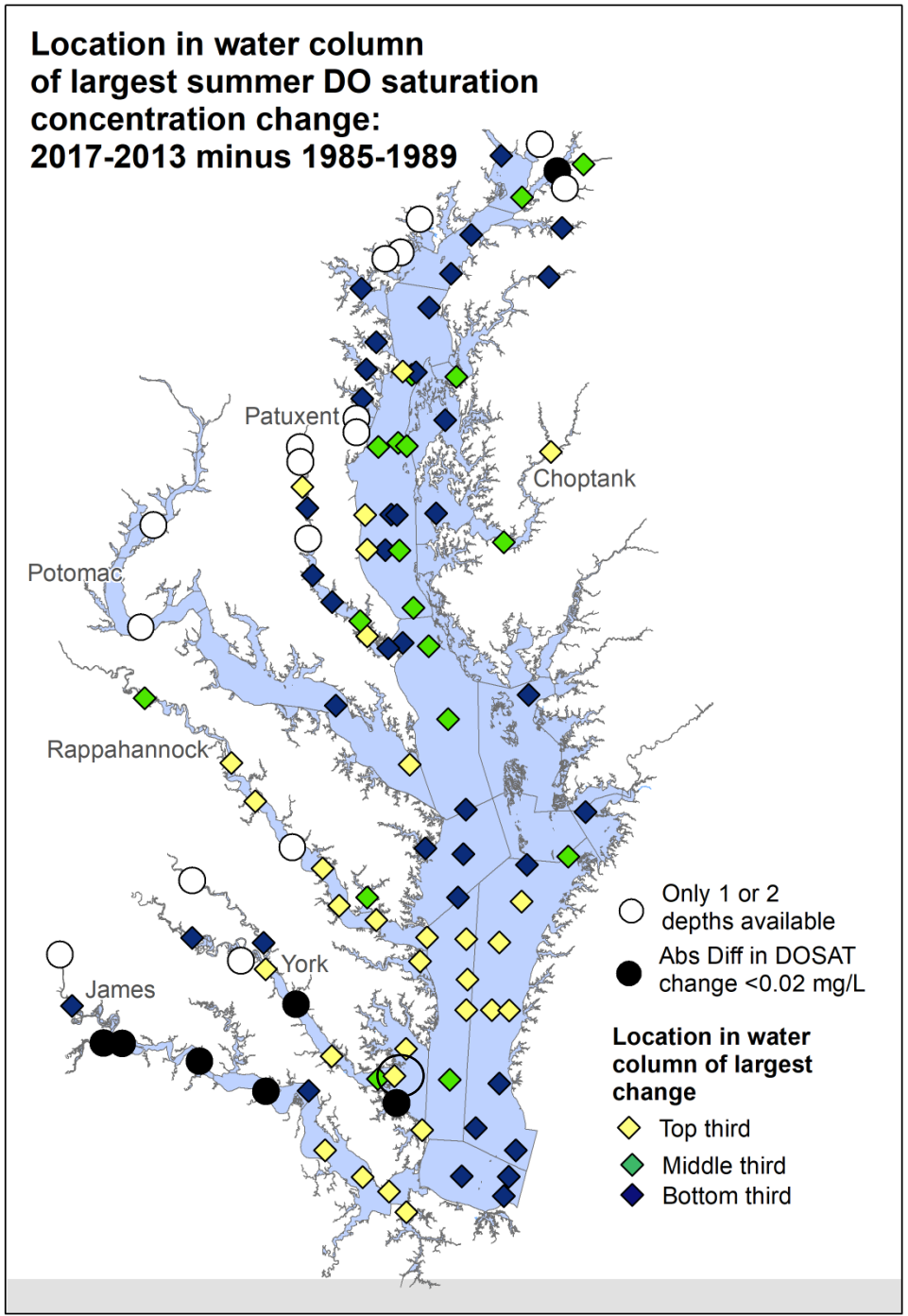

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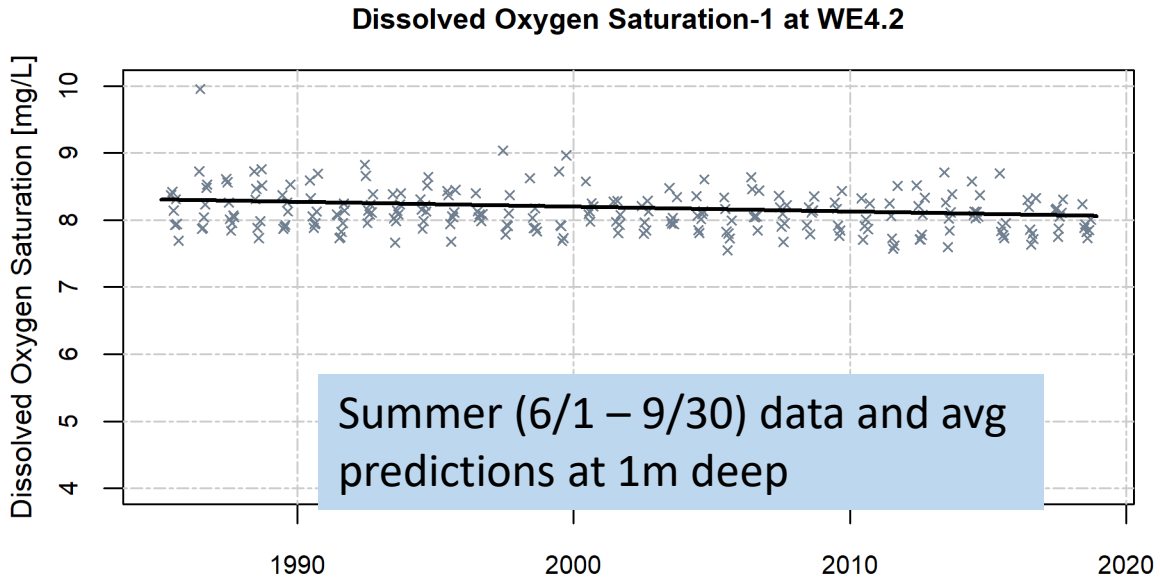

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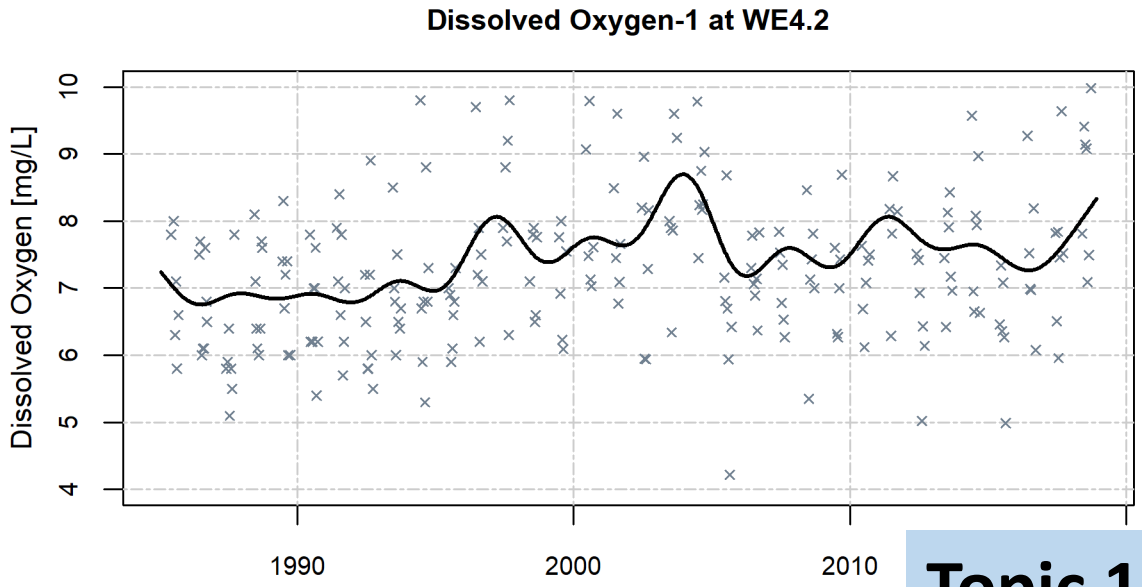
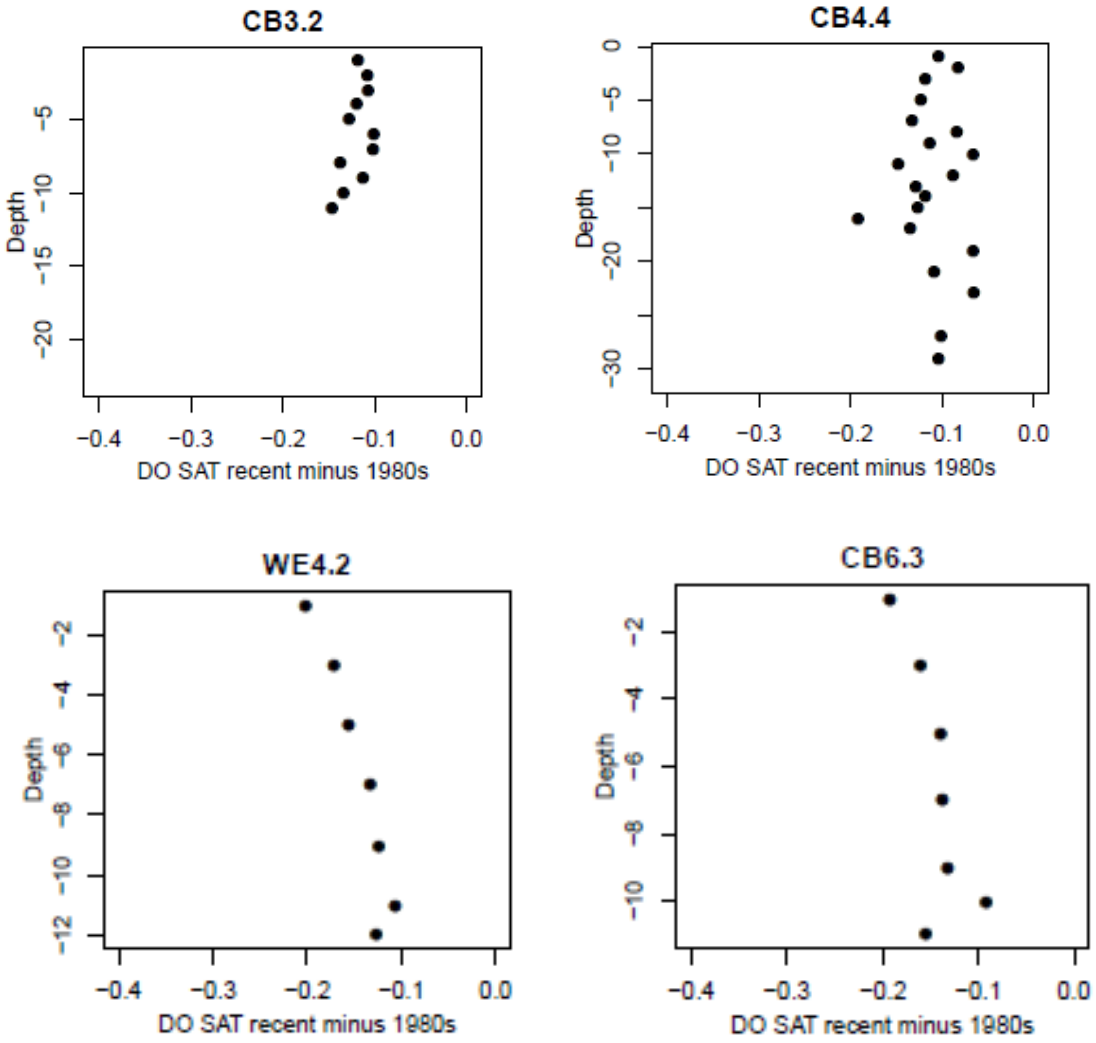


Topic 1: OW

Open Water DO Saturation: How do these compare to model results?

Monitoring: Summer difference between 2013 to 2017 minus 1985 to 1989



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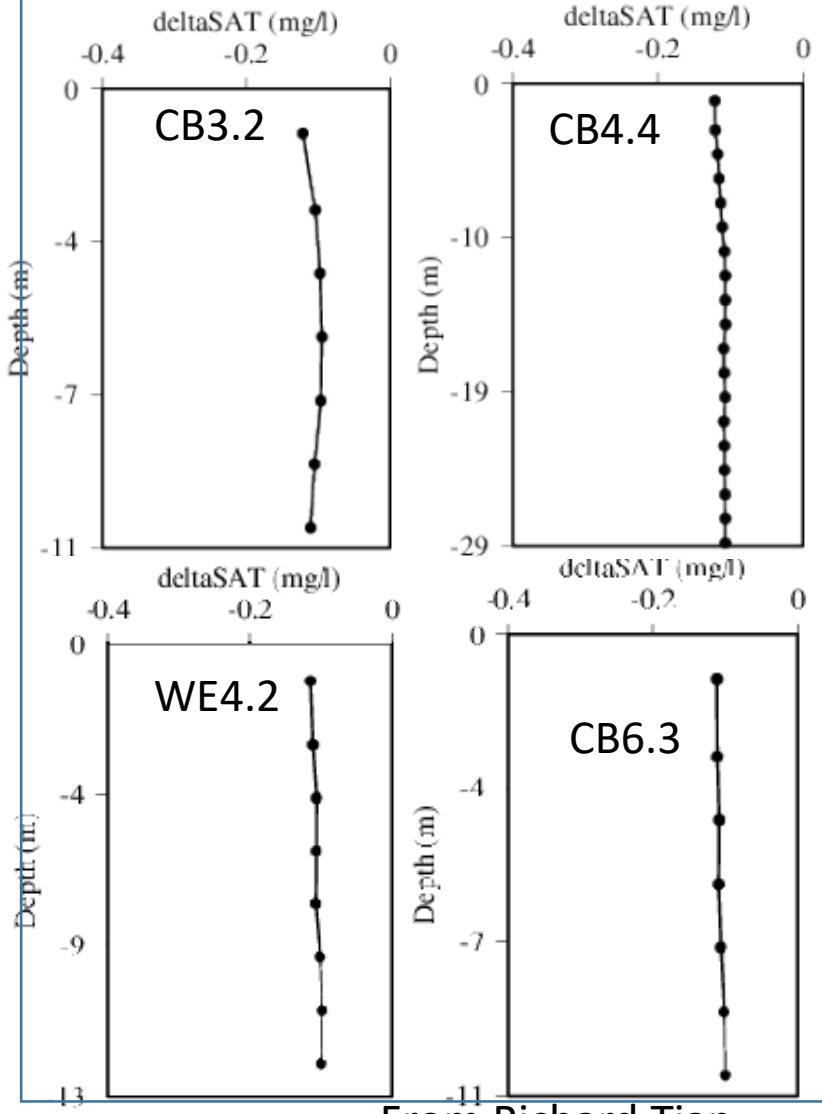


- Magnitude of changes in DO saturation from the model scenarios and 30-year data changes are similar baywide.
- Patterns of DO sat change with depth match temp change patterns exactly.

From Richard Tian

Topic 1: OW

Open water summary

- Water temperature is increasing and DO-saturation concentrations are decreasing at almost all depths and stations baywide (looking at summer results).

- Evaluation of the long-term data does not support the idea that surface waters are universally getting warmer faster than the deeper waters.
  →Although this is the case in some locations, perhaps more in the southern bay

- The magnitude of model-generated changes over 30 years are similar to the data, but the location of maximum modeled change in the water column does not always match the data.

- Future work could include examining changes in spring and fall and more detailed comparison with model results.

Topic 2: Shallow Water (SW)
CBP Modeling Team Question

CBP climate change scenarios predict that DO in “shallow” waters (~1-3m total depth to bottom) will be more impacted than Open Water. ***Are the monitoring data showing evidence of this effect?***

Approach:

1. Evaluate whether the frequency of DO criteria violation has increased at a select set of shallow water monitoring stations over the period of record.

2. Investigate how water temperature change relates to DO criteria violation in shallow waters.

3. Compare temperature and DO trends in shallow water monitoring data to nearby long-term monitoring stations.

Stations

MD Stations (13+ years)

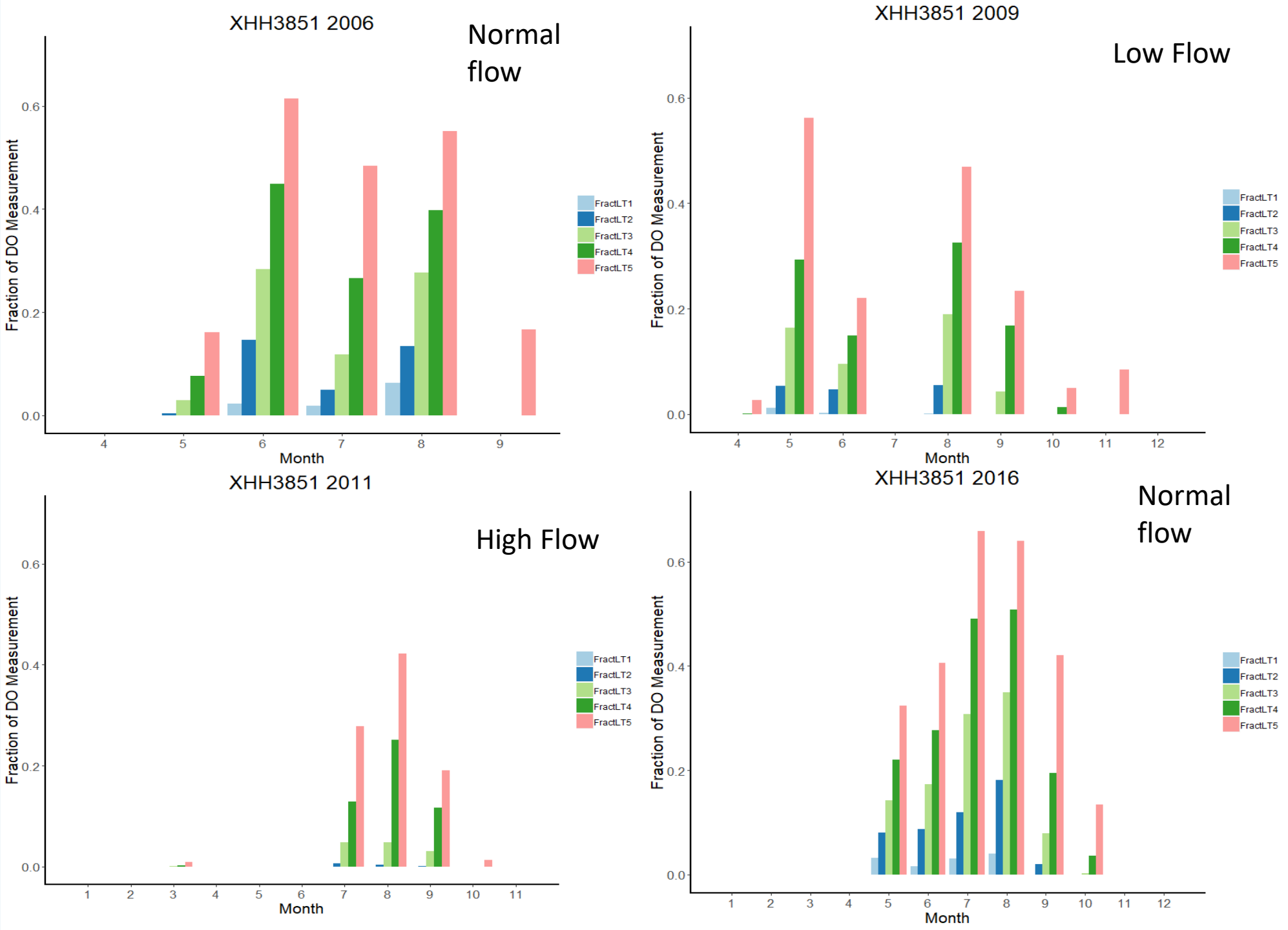
- **Chester River**
  - XHH3851: 2005 – 2016
  - XHH4931: 2006 – 2016
- **Jug Bay**
  - WXT0013: 2003 – 2018
  - PXT0455: 2003 – 2018
  - MTI0015: 2003 – 2018
- **Wicomico River**
  - LMN0028: 2006 - 2018
- **Potomac River**
  - XBF7904: 2006 - 2018
- **Sandy Point**
  - XHF0460: 2004 - 2018
- **Bush River**
  - XJG7035: 2003 - 2018

Proposed VA Stations (13+ years)

- **York River**
  - CHEO19.38: 2006 - 2019
  - TSK000.23: 2005 -2019
  - YRK005.40: 2005 -2019
  - YRK015.09: 2005 -2019
- **Pamunkey River**
  - PMK012.18: 2005 -2019
  - PMK034.00: 2005 -2019

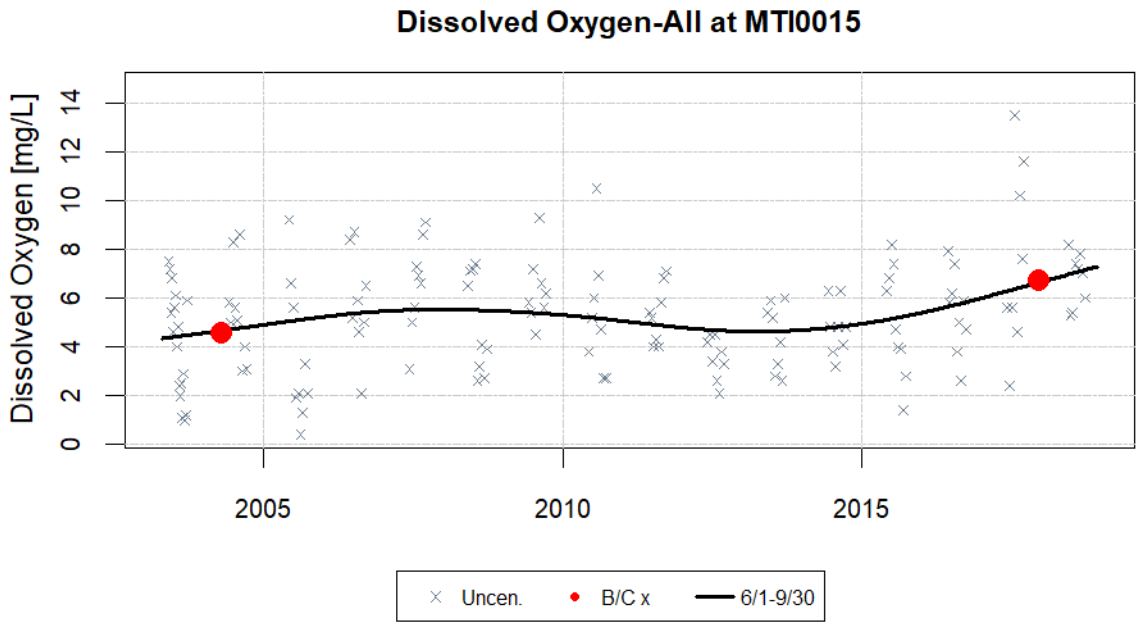
Approach #1: Evaluate whether the frequency of DO criteria violation has increased at a select set of shallow water monitoring stations over the period of record.

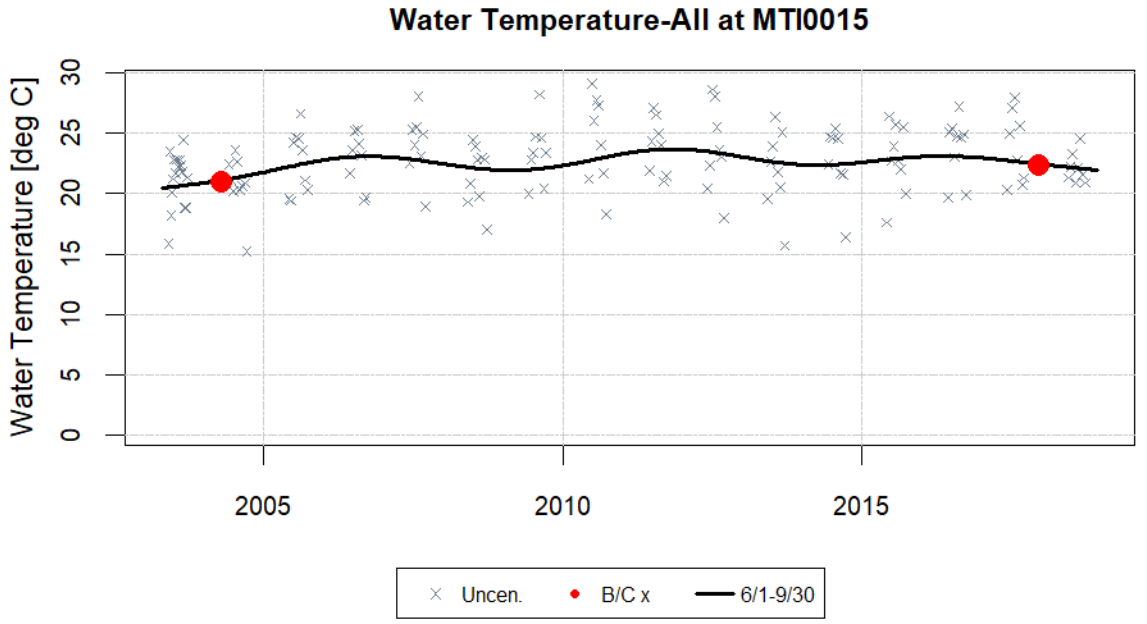
- Results calculated for each year data is available
- Largest amount of criteria violation during summer months
  - Criteria violation starting early (March/April), ending late (Oct/Nov)
- Analysis of these results is ongoing



Approach #2: Investigate how water temperature change relates to DO criteria violation in shallow waters.

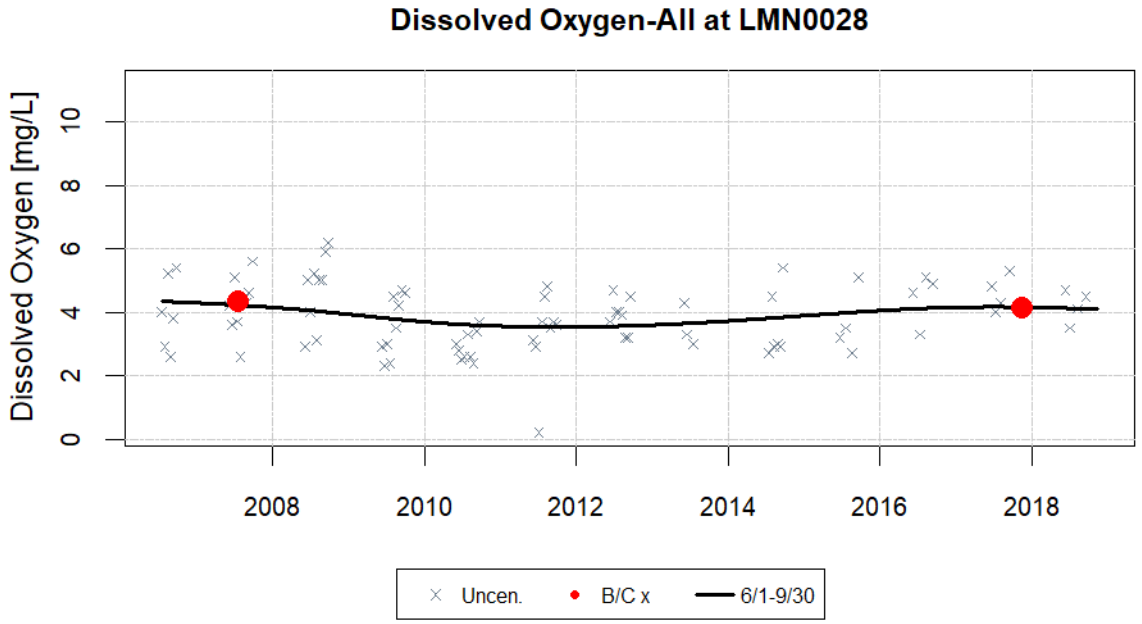
- Fitted GAMs to ConMon calibration data during the summer months to look at trends for WTEMP & DO over the period of record
  - Only fitted to MD stations; still need to evaluate results
- Preliminary findings:
  - In this example, MTI0015 (Jug Bay) DO significantly increased

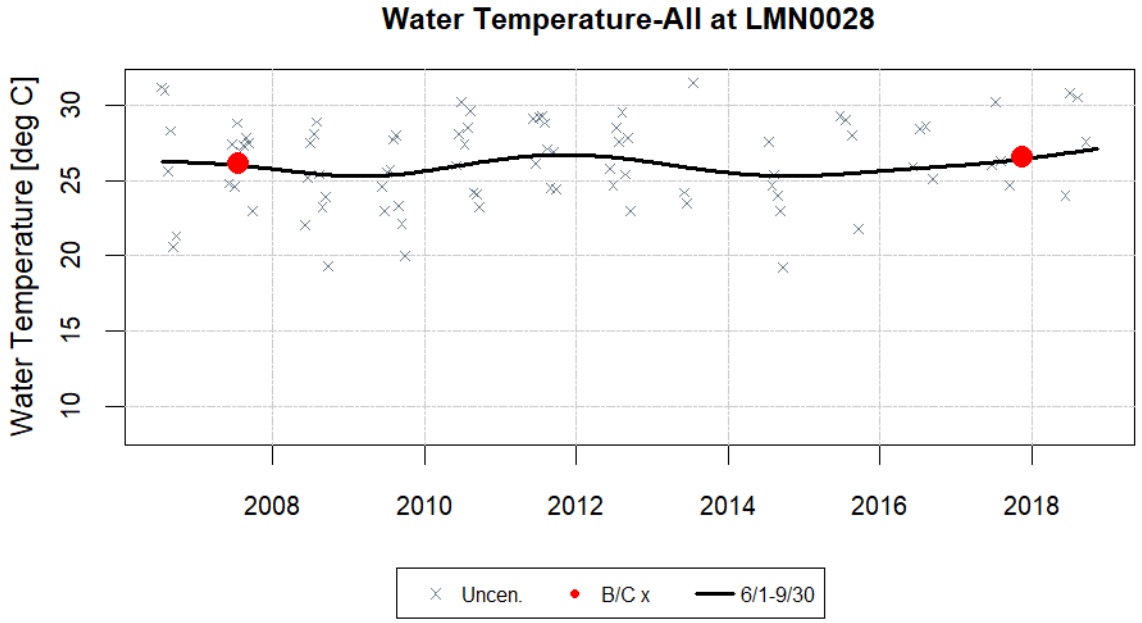




Approach #2: Investigate how water temperature change relates to DO criteria violation in shallow waters.

- Preliminary Findings:
  - WTEMP increases for all MD stations, although change appears small
  - LMN0028 (Wicomico River) only station where AVG summer GAM result below 5 mg/L





Next Steps

- Gather calibration data for VA to choose sites with longer timeseries
  - Run GAMs on DO & WTemp calibration data
- Run GAMs on DO saturation calibration data for both MD & VA stations
- Comparison of temporal GAMs fit at these longer ConMon stations to the closest long-term monitoring stations during the same years of sampling.
  - look at the temporal patterns, compare magnitude, and any trends to nearby long-term stations

Concurrent Shallow Water Monitoring Projects:

- **STAC Proposal w/ Jeremy Testa (UMCES):** Quantifying the impacts of past and future climate and eutrophication on the dynamics of dissolved oxygen in the shallow waters of Chesapeake Bay
- **VADEQ:** Tish Robinson evaluated the CBP DO short-term duration criteria using VA ConMon data from 2016 – 2018.

Questions?

Topic 1: Open Water (OW)

- CBP climate change scenarios predict that over approximately a 30-year period, summer DO concentrations in the Open Water (OW) designated use will be more negatively affected by climate change than summer DO in deeper layers. ***Do the magnitudes and depths of observed changes in the monitoring data support the modeling results that OW is more negatively affected than deeper water?***

Topic 2: Shallow Water (SW)

CBP climate change scenarios predict that DO in “shallow” waters (~1-3m total depth to bottom) will be more impacted than Open Water. ***Are the monitoring data showing evidence of this effect?***